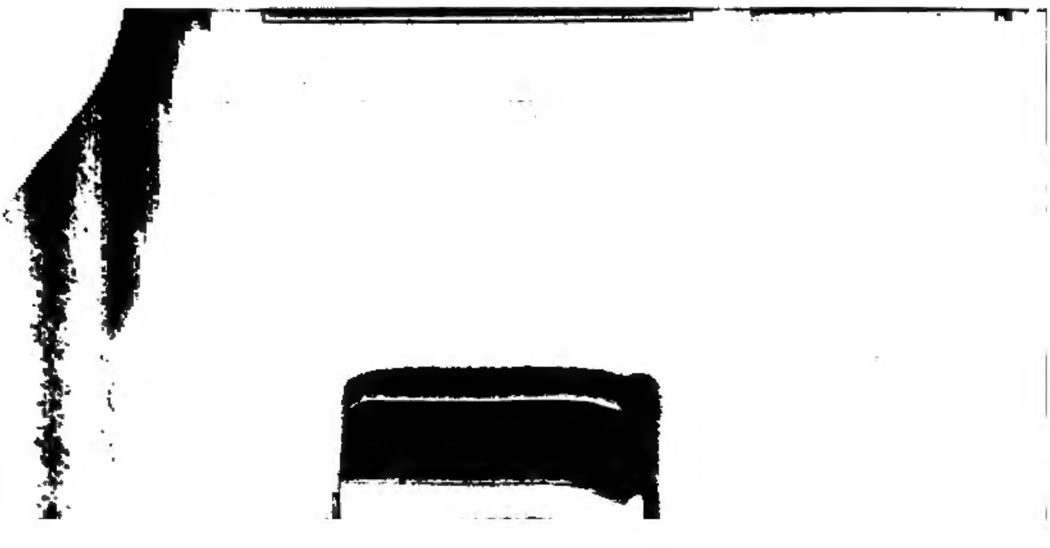
ERRATA

Page 78, line 4, for Homestead, read Olmsted.
Page 78, line 25, for North Dakota, read Northwestern.
Page 84, line 20, for the Indians, read Indiana.
Page 110, lines 1 and 4, omit quotation marks.
Page 112, line 31, for III, read VII.
Page 118, line 17, for VI, read V.
Pages 124 and 125, heading of last column, for pounds, read bushels.

Montana Agricultural Experiment Station, Bulletin 107



MONTANA AGRICULTURAL COLLEGE
EXPERIMENT STATION
F. B. LINFIELD, Director

BULLETIN NO. 104

Tomato Tests

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BOZEMAN, MONTANA
February, 1915

MONTANA AGRICULTURAL COLLEGE EXPERIMENT STATION

BOZEMAN, MONTANA

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Tomato Tests

The climate of the Gallatin Valley is typical of that of many of the other higher mountain valleys of the State. The growing season is short, the maximum summer temperature rarely rising above 90 degrees, and the nights are uniformly cool. Naturally such localities are not well adapted to the growing of tomatoes and even in those sections of the State where the growing season is longest and warmest tomatoes require the best of care if they are to be grown profitably.

FIG. 1. 1 and 3, plants large enough for the first transplanting; 2, ready for second transplanting.

The tomato tests were begun in 1902 with two definite objects in view. First, to determine the best varieties for the higher altitudes of the State; and, second, to work out methods of culture which would tend to induce early ripening of the fruit. The data gathered in 1902 and 1906 appear in the Tenth and Thirteenth Annual Reports of the Experiment Station but are again published with the results of tests in 1911, 1912, and 1913, that the records may be complete and conclusions drawn from all available data.

In all the pruning work the plants were trained to a single stem. The first pruning was usually given about the time the plants were set in the field or when about the size of those in figure 2 and consisted in breaking out all the side branches as they appeared. The single stem was trained to a stake 4 to 5 feet high and was cut off when it reached the top, as shown in figure 4. A plant so treated expends its energies in developing the fruit already set rather than in making more growth and forming more fruit. Pruned plants were set 1 foot 6 inches apart in rows 3 feet apart, and unpruned plants 3 feet apart each way. Pruned

plots then contained double the number of plants in unpruned plots, and the initial cost of plants and planting was, of course, considerably more for the former.

In 1902 twelve varieties of tomatoes were tested. Seed was planted in April and the seedlings shifted first to shallow boxes and then to pots. They were set in the field June 3d and the vines were killed by frost September 12th. The growing season was of average length. The results of the work are given in Table I. Chalk's Early Jewel and the Early Ruby were the two most promising varieties. Had the plants been started earlier, as in later years, better yields could have been secured.

TABLE I. TOMATO TESTS, 1902

Variety	First ripe	Ripe fruit (pounds)	Green fruit (pounds)	Total per cent ripe	Ripe fruit to an acre (pounds)
Mikado	Aug. 13	16.75	40	29.5	3040
Quarter Century	July 23	13.5	26	34.1	2470
Chalk's Early Jewel	Aug. 5	25	[illegible]	41.6	4537
Dwarf Champion	July 28	19.125	27	41.4	3470
Ponderosa	Aug. 5	18.62	61	23.3	3379
Early Ruby	Aug. 3	27	67	28.7	[illegible]
Livingston's Stone	Aug. 13	13.51	30	31	2450
Burpee's Noble	Aug. 26	1.43	28	4.9	259
Perfection	Aug. 15	3.5	47	[illegible]	635
Matchless	Aug. 23	2.69	....	....	486
Stone	Aug. 23	.75	....	—	136
Giant Tree	Sept. 1	.187	....	....	33

sandy. Seventy plants of each variety were set. Thirty-five of these were pruned and trained to a stake and the others were allowd to grow naturally—unpruned and prostrate on the ground.

Both pruned and unpruned plants were frequently irrigated and cultivated until July 15th but received neither irrigation nor cultivation after that date. The results are recorded in Table II. To make these comparable with later data, yields have been recalculated on the assumption that the unpruned plants were set 3 by 3 feet and the pruned plants 3 by 1½ feet as they were planted in 1911, 1912, and 1913.

TABLE II. TOMATO TESTS, 1906

Variety	First ripe		Yield per acre (pounds)				Increase in ripe fruit due to pruning (pounds)
			Ripe		Green		
	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned	
Matchless	Sept. 8	Sept. 29	19,014	4,010	10,366	23,196	15,004
Dwarf Golden Champion	Aug. 26	Sept. 14	15,898	3,319	3,350	1,314	12,579
Climax	Sept. 1	Sept. 29	29,593	3,388	8,920	28,068	26,205
Trucker's Favorite	Sept. 6	Oct. 6	17,285	553	14,543	20,535	16,732
Burpee's Earliest Pink	Aug. 26	Sept. 14	48,400	28,071	12,861	53,929	20,329
Bolgiano's Prolific IXL	Sept. 1	Sept. 14	34,156	26,929	6,913	43,351	7,227
Earlibell	Aug. 24	Sept. 13	38,996	13,551	13,414	21,672	25,445
Acme	Aug. 26	Sept. 24	32,806	7,052	11,339	27,656	25,754
Spark's Earliana	Aug. 23		41,416	19,764	8,091	53,514	21,652
Greater Baltimore	Sept. 1		32,806	3,318	3,507	27,241	29,488

These tomatoes were planted March 23, first transplanted April 8, shifted to 4-inch pots between May 5 and 20, and set in the field June 11.

Burpee's Earliest Pink produced the largest amount of ripe fruit. The best three varieties, considering quality and yield, were Earliana, Earlibell, and Burpee's Earliest Pink. These three varieties also ripened the first fruits. Pruned plots of the earliest varieties produced ripe fruits at least twenty days earlier than unpruned plots of the same variety. Pruning also greatly increased the total yield of ripe fruit.

The season of 1911 was about an average growing season and the tomato plots produced very good yields of ripe fruit. (Table III). The pruned plants produced the first ripe fruits; and in the case of the earliest varieties, pruned plots produced three and four times as much ripe fruit as unpruned plots of the same varieties. Earliana, Bonny Best and June Pink ripened the most fruit. Dwarf Champion and Matchless produced no ripe fruit and are entirely too late for our short season.

TABLE III. TOMATO TESTS, 1911

Variety and source of seed	Yield per acre (pounds)				Increase in ripe fruit due to pruning (pounds)
	Ripe		Green		
	Pruned	Unpruned	Pruned	Unpruned	
Spark's Earliana (Dreer)	19,402	7,174	15,817	72,240	12,228
Spark's Earliana (Burpee)	18,842	435	12,984	58,429	18,407
Earliana (Ontario Seed Co.)	14,655	6,020	18,591	54,652	14,635
Chalk's Early Jewel (Dreer)	4,957	361	21,129	18,060	4,596
Chalk's Early Jewel (Burpee)	9,424	177	26,624	41,255	9,247
Chalk's Early Jewel (Ont. Seed Co.)	2,714	331	23,371	39,425	2,383
My Maryland (Bolgiano & Sons)	5,304	354	16,171	16,938	4,950
Bonny Best (Dreer)	11,346	2,891	20,251	31,104	8,455
June Pink (Dreer)	11,685	8,403	23,077	66,102	3,282
Comet (Dreer)	3,069	2,319	18,237	29,569	650
Dwarf Champion (Dreer)	Too late				
Matchless (Dreer)	None	None	1,947	14,873	

These tomatoes were planted March 28, transplanted to 2-inch pots between April 22 and 29, shifted to 4-inch pots between May 18 and 23, and set in the field June 14 to 16.

The growing season of 1912 was unfavorable for tomatoes. Only a few ripe fruits were obtained. The yields of green fruit are given in Table IV. Strains of the most promising early varieties were secured from various sources and tested with strains of our own selection. This season's work was really planned as a beginning of our efforts to breed up earlier strains by selection.

TABLE IV. TOMATO TESTS, 1912

Variety and source of seed	Yield per acre of green fruit (pounds)	
	Pruned	Unpruned
Langdon's Earliana (Langdon)	11,539	24,053
Earliana (Ontario Seed Co.)	32,464	23,000
Spark's Earliana (Burpee)	15,494	50,067
Earliana (Station)	12,972	18,003
Spark's Earliana (Dreer)	13,366	26,170
Chalk's Early Jewel (Burpee)	12,676	20,098
Chalk's Early Jewel (Station)	12,568	20,207
Bonny Best (Station)	10,465	17,250
Comet (Station)	8,857	14,843
Bolgiano's Prosperity (Bolgiano & Sons)	11,456	19,880

These tomatoes were planted May 16, first transplanted April 12, shifted to 4-inch pots May 3 and 4, and set in the field June 11 to 14.

FIG. 3. Good method of irrigation, especially for heavy soils.

Tomatoes tested in 1913 were largely our own selection from the crop of 1912. Pruning tests were continued but not with as large plots as in 1911 and 1912. The results given in Table V do not represent all the work of 1913. In each variety several strains (selections from individual plants) were tested. We have selected one strain of each variety with average yield to show the benefits derived from pruning, with no attempt to show the merit in our own selections. The last seven varieties in the table are tests of seed donated for trial by the Dakota Improved Seed Company, Mitchell, South Dakota. The benefits derived from pruning are again apparent in this year's results. The results with varieties emphasize our limitations in tomatoes adapted to our short season. None but the earliest will give profitable returns.

TABLE V. TOMATO TESTS, 1913

Variety and source of seed	First ripe		Yield per acre of ripe fruit (pounds)		
	Pruned	Unpruned	Pruned	Unpruned	Increase due to pruning
Bolgiano's Prosperity (Station)	Aug. 6	Aug. 19	12,250	4,197	8,053
Earliana (Station)	Aug. 6	Aug. 6	9,332	3,982	5,350
Chalk's Early Jewel (Station)	Aug. 19	Aug. 6	7,058	2,747	4,311
Bonny Best (Bolgiano & Sons)	Aug. 19	Aug. 19	9,237	2,873	6,364
Disco Thornber (So. Dakota Seed Co.)	Aug. 6	Aug. 19	7,682	3,297	4,385
Disco "99" (So. Dakota Seed Co.)	Sept. 5	Sept. 19	908	113	795
Disco Pink (So. Dakota Seed Co.)	Aug. 6	Aug. 19	5,445	1,558	3,887
Disco Giant (So. Dakota Seed Co.)	Aug. 19		378	None	378
Chalk's Early Jewel (So. Dakota Seed Co.)	Aug. 19	Aug. 26	4,538	340	4,198
Earliana (So. Dakota Seed Co.)	Aug. 6	Aug. 19	9,900	3,467	6,433
Acme (So. Dakota Seed Co.)	Sept. 5	Sept. 12	3,993	454	3,539

These tomatoes were planted March 24, first transplanted April 10 and 11, shifted to 4-inch pots May 6 to 13, and set in the field June 11 and 12.

CONCLUSIONS

The data given indicate that tomatoes can be successfully grown in the higher altitudes of the State when properly started and cared for. It is first necessary to get the plants started early. Those shown in figure 2 are of about the right size. These are nine weeks old from seed. The plants are best grown in pots or

FIG. 4. A pruned plant with a promising crop of fruit.

boxes so they can be transplanted to the field without seriously injuring the root system.

Early varieties should be chosen, and of those tested Earliana, Chalk's Early Jewel, June Pink and Bonny Best have proved most promising.

Pruning and training are decidedly beneficial both from the standpoint of early ripening and quantity of fruit ripened. First ripe fruits are usually produced at least two weeks earlier by pruned vines. Pruned plots have in nearly every case produced from three to five times as much ripe fruit as unpruned plots. Pruning does reduce the total amount of fruit produced, when both green and ripe fruit are considered, but green fruit is usually of little value. Pruning and training are not expensive operations and pay well.

FIG. 5. A field of staked plants, September 1st.

MONTANA AGRICULTURAL COLLEGE
EXPERIMENT STATION
F. B. LINFIELD, Director

BULLETIN NO. 105

The Intradermal Test in Bovine Tuberculosis

BY
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BOZEMAN, MONTANA
February, 1915

MONTANA AGRICULTURAL COLLEGE EXPERIMENT STATION

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The Intradermal Test in Bovine Tuberculosis

THE RELATION OF BOVINE TUBERCULOSIS TO PUBLIC HEALTH

It has been known definitely for a long time that tuberculosis in cattle and tuberculosis in man are one and the same disease. Thousands of instances can be cited where this disease in children has been traced directly to the milk of a tuberculous cow, and there is no doubt that a large percentage of the cases among children in our large cities is caused by milk from tuberculous dairy cattle. We are daily called upon to contribute in one way or another to the campaign against tuberculosis in man, but it seems an uphill task when infected dairy cattle are creating new cases faster than they can be provided for.

TUBERCULOSIS AS A STOCKMAN'S PROBLEM

Entirely aside from the fact that tuberculous cattle endanger the lives of their owners and other human beings, tuberculosis causes tremendous losses among the cattle themselves. By reason of its stealthy, insidious development, 50 to 75 per cent of a herd may be diseased before the owner becomes aware of it. It is not uncommon for 90 per cent of a dairy herd to react to the tuberculin test.

All breeds of cattle seem equally susceptible, but the largest losses are among the dairy breeds, since the method of handling them is conducive to the spread of infection. There is a common impression that range cattle are not subject to tuberculosis, but this is erroneous. Very few of the range herds in the Northwest have ever been tested but such as have, proved to be tuberculous to some extent. No doubt many a cow that failed to live through a hard winter died because she was weakened by tuberculosis. The time has already come when public sentiment compels the tuberculin testing of all dairy cattle. The time will come when packers will refuse to stand the loss of tuberculous cattle condemned on the killing floor, and the shipper will have to look out for them as he does for the lumpy jaw cases now. When this time comes,

FIG. 1. This cow was a heavy milker and rated as the best cow in a large dairy. She was tested, reacted, and was found extensively tuberculous.

FIG 2. This animal was also used as a milk cow. When photographed she had been known to be tuberculous for a year.

FIG. 3. A visibly tuberculous animal.

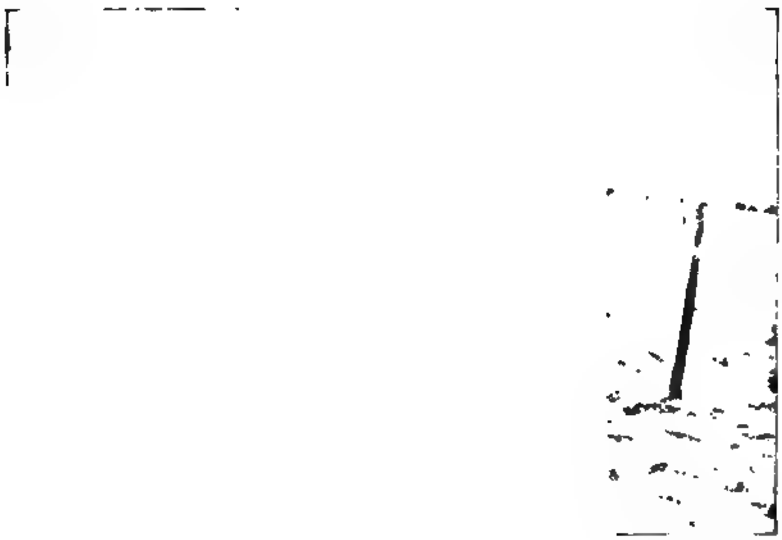

FIG. 4. Another tuberculous cow. Her appearance and condition would not indicate anything wrong.

the owner of a tuberculous range herd or of diseased breeding stock will have to use the tuberculin test or go out of business.

NATURE OF TUBERCULOSIS

Tuberculosis is one of the oldest of animal diseases. Years ago it was shown beyond a doubt to be a germ disease, communicated from one animal to another by germs, and by germs alone. Like diphtheria, smallpox, or any other contagious disease, tuberculosis is caused solely by infection from some other case. Though nearly all animals are susceptible, cattle are the most easily affected, and for the purposes of this bulletin we shall consider it from the aspect of a cattle disease. Tuberculosis is slow and insidious in its development, which characteristic has enabled it to gain such a foothold in our cattle herds. A cow may be tuberculous for several years and show absolutely no indications of ill health, yet every day spread germs in watering troughs, mangers, salt boxes, etc., infecting many other cattle. These germs are soon destroyed by sunlight but will live for a long time in dark corners, buildings, etc. So in dark, poorly lighted and ventilated barns, when tuberculosis once gets started a large percentage of the herd will contract the disease in a relatively short time.

FIG. 5. A group of infected cattle. When slaughtered these were all found to be tuberculous.

HOW TUBERCULOSIS IS SPREAD

The germs from a tuberculous cow may pass from her body in the saliva, milk, or manure. The milk may swarm with germs direct from a lesion in the udder or may be contaminated by dust and particles of manure falling from the cow's flank. Straining does not remove anything but the larger particles, so that, unless pasteurized, milk from a herd where tuberculosis exists is very likely to cause the same disease in calves and hogs. The saliva from a tuberculous cow keeps feed-racks, mangers, and watering-troughs constantly infected, and the swallowing of saliva infects the bowel contents, thus spreading disease by means of the manure.

A cow may be tuberculous for several years without showing any indication of disease, or she may break down and die in a few months. Much depends on the conditions under which the animal

FIG. 6. A piece of the diaphragm or "skirt" from a tuberculous cow, showing the clustered tubercles on the surface.

is kept. It is never safe to keep in a herd a cow that has once reacted to the tuberculin test, no matter what her appearance may be. A healthy herd seldom gets infected unless a tuberculous cow is placed with it. Nearly all tuberculosis in this State can be traced to infected stock shipped from the older states.

SYMPTOMS OF TUBERCULOSIS

There is no symptom that can be depended upon. No stockman, dairyman, or veterinarian can pick out half the tuberculous cattle in any herd simply by an examination of them. The diseased cattle may cough, or they may not. They may be fat or thin or in medium condition. One infected cow may have a cough, be emaciated, etc., and another, equally diseased, show no such symptoms. Again, there are many instances of cows having every symptom of tuberculosis—cough, wasting away, weakness, etc.—where the trouble is due to other causes. The tuberculin test is the only

FIG. 7. One of the oval lymph glands from between the lungs of a cow affected with tuberculosis. The rounded, light-colored bodies are centers of disease.

method that will enable one to pick out the diseased animals in a herd.

POST MORTEM APPEARANCE OF TUBERCULOSIS

Any of the organs of the body may be diseased, but tuberculosis is generally found in the lymphatic glands, the lungs, and the liver. The lymphatic glands lie in groups,—one around the throat, another between the lungs, another near the liver, and a chain of them the full length of the intestine. These glands normally are small, rounded, dark gray bodies, from the size of a pea to that of a man's thumb. When affected with tuberculosis they become lumpy, enlarged (frequently the size of a baseball), and when cut open, show tubercles full of a yellow, cheesy material, which in old lesions becomes gritty and dry like sand (fig. 7). The lungs may show nothing externally, but, if the hand be passed over the surface, lumps of various sizes may be felt, which when cut open show the cheesy, yellow abscesses of tuberculosis (fig. 8). The liver may

FIG. 8. Diseased lung, showing the white areas of pus caused by tuberculosis.

have large abscesses (fig. 9), or may have small tubercles scattered through its substance or lying entirely upon the surface (fig. 10). When an animal is condemned and slaughtered for tuberculosis, there may be no indication as to the location or extent of the disease. Lesions may be plentiful in every organ, or a careful search may be necessary to find the one lymphatic gland that contains the tubercle.

Cases that have tuberculous lesions directly open to some passage leading to the outside, as in the lungs, the intestines, the udder, etc., are called open cases, but where the lesions are confined to glands, etc., and the germs cannot escape directly to the outside, they are called closed cases.

THE TUBERCULIN TEST

The tuberculin test for the detection of tuberculosis in cattle was perfected many years ago and has been adopted by all civilized

FIG. 9. Tuberculous abscesses in the liver.

FIG. 10. Tubercles on the surface of the liver, and one of the lymph glands from near the liver.

nations. Statistics covering thousands of tests conducted by many different men show the test to be 98 per cent accurate, and in the hands of very careful, skilled veterinarians it has proved practically 100 per cent accurate. At the present time no intelligent man criticises the tuberculin test as a means of accurately determining the presence or absence of tuberculosis in cattle. To quote Dr. James Law, "Much has been said and written against the tuberculin test by those that have never used it, and are therefore utterly incompetent either to indorse or condemn it, but for those who aim at a prompt and thorough eradication of tuberculosis from their herds . . . . no resort, as regards efficacy, can compare with the tuberculin test."

The test consists of—

1. Taking the temperature of a cow a sufficient number of times to determine its normal range.

2. Injecting tuberculin,—2 c.c. for the average cow.

3. After a lapse of six or eight hours, taking the temperature every two hours until twenty hours after the injection.

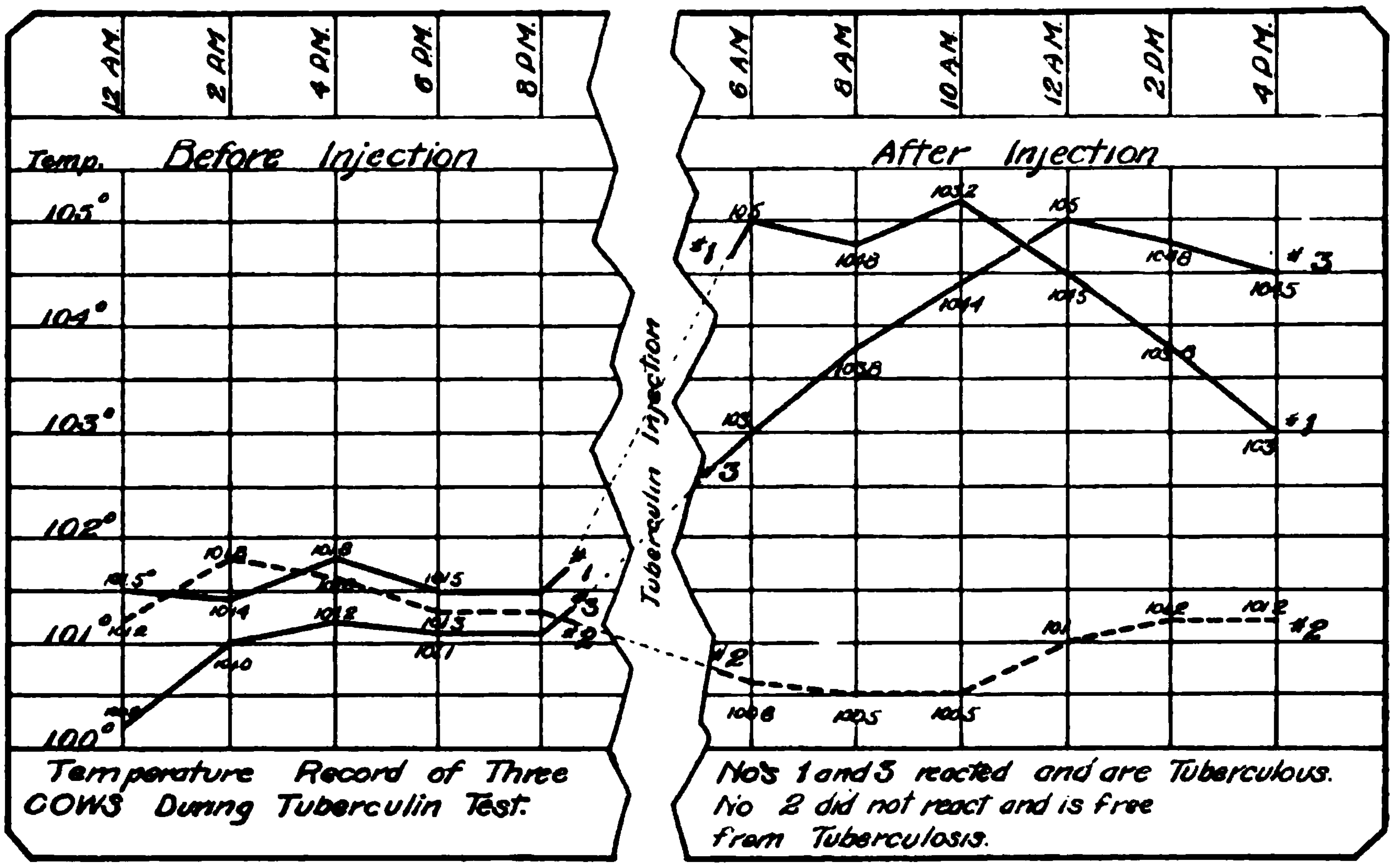

FIGURE 11.

If no tuberculosis exists, the second set of temperatures will be approximately the same as the first. If the cow is tuberculous, the second set will be higher by two degrees or more, and the elevation will persist through several hours.

Figure 11 shows some typical tuberculin reactions and also temperatures from a healthy cow.

THE NECESSITY FOR RETESTING

The testing of the herd and the removal of the reacting cattle does not necessarily end the trouble. The remainder, particularly the older cattle, must be regarded with suspicion. There is a constant effort on the part of the tissues of the animal body to resist the progress of disease, and such opposition often takes the form of surrounding and walling off the diseased area with a capsule of firm connective tissue. If this wall of tissue is complete, the disease for the time being is inactive, and very frequently the cow will not react to the tuberculin test. However, the disease may sooner or later break through this capsule and become active, after which the cow will react to the test.

Again, where tuberculosis has gained quite a foothold it is

always possible that some cow has contracted the disease just before the herd was tested. This cow will not react. It is therefore necessary, if we would detect all the tuberculous animals, to test the herd three or four times, at intervals of six to eight months. Afterward a test once a year will be sufficient. It is a long process to entirely wipe out tuberculosis from a badly infected herd but persistent retesting will do it.

CONDITIONS INFLUENCING THE TEST

Since the reaction to the tuberculin test is essentially a matter of an elevation of temperature, it is evident that cattle should not be tested while any other condition exists that might raise the temperature. Most common among these are advanced pregnancy—a week before or after calving; oestrum or the period of heat; conditions that tend to greatly excite the cattle; very hot weather, hot barns, etc.; caked udder, retained placenta, pneumonia, or any other condition likely to cause a fever. While it is a fact that these things will raise the temperature of a cow sufficiently to resemble a reaction, in 90 per cent of the cases fever will be manifest in taking the preliminary temperatures, and the affected animal should be turned out and tested at some other time.

The Intradermal Tuberculin Test

The subcutaneous or thermal test, with its temperature curves, is the pioneer of the tuberculin tests and has proved its worth, but the other tests—the ophthalmic or eye test and the intradermal or skin test—are gaining ground rapidly. It was after the reported successful operation of the intradermal test in Missouri that it was decided to try some experiments with it in Montana. The results have exceeded our expectations.

Though requiring experience to correctly interpret results, the

FIG. 12. An intradermal reaction, unusually large and well defined.

intradermal test equals the thermal in accuracy and in many particulars far excels it. It economizes time, labor, and materials. It renders the work easier for the veterinarian and makes less trouble for the dairyman. State inspectors can more than triple the number of cattle that can be tested by the thermal method. The intradermal test has also made possible the rapid testing of large range herds. When the various States officially adopt this method, a great advance will be made in the national fight against tuberculosis.

TECHNIQUE OF THE TEST

In the subcutaneous or thermal method, a large amount of tuberculin—2 to 4 c.c.—is injected into the connective tissue under the skin. In the intradermal method, 3 to 5 minims, or about 1-3 to 1-5 c.c. is placed by a short, small-gauge needle (fig. 13), not through the skin but into its deeper layers, the site selected for

FIG. 13. Syringe and needles for intradermal testing.

FIG. 14. Making an intradermal injection with an assistant.

the injection being the smooth skin under the base of the tail. The exact point will differ in each animal, but we have found that the most favorable point is where the caudal fold merges with the tail, probably two to three inches from the anus (fig. 14).

The operator stands on the right side of the animal, driving the right knee firmly into the flank, with the right arm resting on the hips (fig. 14). The needle is thus pointing in the caudal direction, and when the injection is made into the posterior border of the caudal fold at this angle, it is impossible to get the tuberculin through the skin. The most hurried injection, made in this way, cannot go far wrong. The injected tuberculin shows immediately at the point of the needle as a firm, spherical swelling the size of a pea, varying, however, with the density of the tissue at that point. Testing can be done most rapidly and accurately with two assistants, one to hold the cow firmly by the head, even if in a stanchion, the other to raise the tail. In this way, allowing for ordinary delays, a veterinarian can inject a cow every fifteen seconds. If the cattle are very quiet, the veterinarian can test them

FIG. 15. Making an intradermal injection without an assistant.

without assistance, pulling out the caudal fold with the fingers of the left hand and not raising the tail (fig. 15). As a rule it is a waste of time to attempt to work alone, as the needle is very short and the slightest move of the cow serves to withdraw it.

If the needle has to be inserted two or three times in the attempt to inject tuberculin, a swelling is likely to form as a result of repeated needle pricks that will persist for some time and may interfere with the diagnosis.

It has not seemed necessary to disinfect the site of injection. A piece of gauze or a soft towel vigorously applied will clean a small area sufficiently to avoid any appreciable infection. A small wad of cotton or gauze, soaked in a disinfectant, may be carried in the hand and the needle disinfected as the operator moves from one cow to another.

In over two thousand tssts applied to range cattle it was impossible even to clean the caudal fold. No swellings resulted from infection, and it is very doubtful if a swelling due to infection could possibly be mistaken for a reaction.

KIND OF TUBERCULIN USED IN THE INTRADERMAL METHOD

There has been a great deal said about special tuberculins for the intradermal method, based on the supposition that the glycerin in the ordinary tuberculin will cause a pseudo-reaction. Many firms advertise special intradermal tuberculins, most of which are alcohol-precipitated and free from glycerin. Many investigators have strongly advocated such a tuberculin. We used the glycerin-free tuberculin on two herds, as follows: On 122 dairy cattle, four small swellings resulting, none of which appeared in any subsequent test; then on 302 yearling Hereford range heifers, with five reactors which were found tuberculous on post-mortem. A retest six months later with ordinary tuberculin gave negative results.

We have used the ordinary tuberculin produced by the U. S. Bureau of Animal Industry, which contains about 5 per cent of glycerin, and in over three thousand tests have not observed any swellings that would be confusing. There have been numerous soft, ill defined thickenings of the caudal fold that would occasionally persist to the third day after injection, but they were not at all typical. The special tuberculin is not adapted to general testing:

first, because it is very expensive; and, second, because it is not stable in solution. It should be handled as a powder and made up into a solution immediately before testing. The Bureau of Animal Industry tuberculin is accessible to practitioners that have much testing to do, and as far as our experiments have gone it serves the purpose as well as the glycerin-free product.

NATURE OF THE REACTION TO THE TEST

The reaction to the intradermal test consists of a swelling, well defined, more or less firm, sensitive, and in most cases definitely circumscribed. Its size varies from that of a hazel-nut to that of an orange. The most common type is an oval, hard, sensitive mass about the shape and size of a hen's egg cut in half longitudinally (fig. 18). The point of injection can be seen near the center as a small dark spot. Quite frequently in a very large swelling a gangrenous area forms, and the dead tissues leave a permanent scar.

FIG. 16. The intradermal reaction,—a hard, well defined swelling in the caudal fold.

Occasionally a swelling will be very diffuse, involving the entire caudal fold and puffing up the skin around the anus, making a swelling 5 to 6 inches long and 2 inches in diameter. If the tuberculin is injected well away from the body, with the bone and connective tissue of the tail to form a solid backing, the reaction will be clear and unmistakable. Swellings forming close to the body may merge with the tail head and perineal tissues and be quite indefinite, especially in fat animals. The swelling reaches its maximum at about the twenty-fourth to the thirtieth hour after injection and usually remains unchanged until the seventieth hour or longer. A large, well defined reaction may persist six or seven days. That shown in figure 19 was photographed on the fifth day and remained definite for some days longer.

In non-reactors a small swelling may appear within three or four hours and disappear in ten or twelve hours, sometimes leaving a small, hard knot to mark the point of injection.

In a great many cases a distinct physical reaction follows the

FIG. 17. A reaction to the intradermal test, somewhat soft and not well defined.

FIG. 18. A very typical reaction,—an elliptical, firm, definite swelling.

intradermal test. In dairy cattle we have seen typical reaction curves following this test. On the range, where no temperatures can be taken, we can pick many reactors simply by riding among the cattle and noting the drowsy, sick appearance of some of them. Dairymen often report loss of milk, chills, and other indications of high temperature on the day following the intradermal test.

INSPECTION OF ANIMALS FOR REACTION

The time to inspect the injected cattle is not necessarily a fixed one. Any typical swelling persisting after forty-eight hours may be considered diagnostic, so that after that period the convenience of the dairy owner and the veterinarian may be considered. In actual field testing, cows are injected at milking-time because they are then in their stanchions and the dairyman is put to no inconvenience. Inspection can be made most easily at the same hour three days later, or seventy-two hours after injection.

If an earlier inspection is desired, forty-eight hours will serve as well in the great majority of cases. If there are no reactors in

a herd, this fact will be as evident at thirty hours as at ninety, but sometimes a soft, atypical swelling will persist long enough to be confusing and will require a later inspection to make certain its diagnostic value. If only one inspection can be made, as in the case of a dairy a long distance out, this inspection should be at the seventieth to eightieth hour.

RETESTING THE HERD

After an intradermal test, a retest of an infected animal in six to eight days will give a distinct reaction. If several retests are made at similar intervals, the reaction becomes less and less characteristic with each injection of the tuberculin.

If the first reaction is very large, it will be necessary to use the opposite caudal fold for the retest. Cattle which give a large and characteristic reaction to the test will give a satisfactory retest at an earlier date than those animals which do not react so positively. As each reaction leaves a small, hard knot which persists for some weeks, the available space for injection is soon used up. Also, repeated injection of tuberculin seems to develop a tolerance in the individual, and a tuberculous animal soon ceases to react to a test.

FIG. 19. One of the large swellings that occasionally occur.

TESTING BY BOTH METHODS SIMULTANEOUSLY

In applying the intradermal and the thermal tests at the same time, no appreciable effect is noticeable on the temperature curve but the size of the local reaction is somewhat modified. As there are cattle that will react to one test but not to the other, it is often wise to use both. It is preferable to use the intradermal test first and then the thermal, as follows: Apply the intradermal test, inspect at about the sixty-fifth hour, and then start taking temperatures for the thermal test. Use 3 to 3.5 c.c. of tuberculin instead of 2 c.c. By this method no more actual time is employed than in simultaneous testing and each reaction is clear and distinct.

USING THE INTRADERMAL TEST AFTER THE THERMAL OR SUBCUTANEOUS

When cattle have been tested first by the thermal method, diseased animals frequently will not react to the intradermal test for at least twenty days, though the exact time has not been determined. Experiments show that there is a great variation among cattle as to the earliest date at which they will react to this second test. This is shown in the following records of experiments.

Cow No. 1.
- Dec. 20, tested intradermally, positive reaction.
- Dec. 24, tested thermally, positive reaction.
- Jan. 6, tested intradermally , positive reaction.
- Jan. 10, tested intradermally, positive reaction.

Cow No. 4.
- June 4, tested thermally, positive reaction.
- June 20, tested intradermally, negative reaction.
- June 26, tested intradermally, negative reaction.
- July 2, tested intradermally, positive reaction.

Cow No. 5.
- June 4, tested thermally, positive reaction.
- June 10, tested intradermally, negative reaction.
- June 20, tested intradermally, small, indefinite reaction.
- July 1, tested intradermally, positive reaction.

Cow No. 6.
- June 4, tested thermally, positive reaction.
- June 12, tested intradermally, positive reaction.
- June 20, tested intradermally, positive reaction.

Cow No. 9.
Sept. 5, tested thermally, positive reaction.
Sept. 15, tested intradermally, negative reaction.
Sept. 21, tested intradermally, negative reaction.
Sept. 27, tested intradermally, positive reaction.

Cow No. 12.
Apr. 2, tested thermally, positive reaction.
Apr. 8, tested intradermally, positive reaction.
Apr. 14, tested intradermally, positive reaction.

From this it may be seen that although cows Nos. 1, 6, and 12 reacted locally within ten days after a subcutaneous injection, Nos. 4, 5, and 9 would not react until about twenty days after. A great number of tuberculous animals will have to be tested and retested before we can set an approximate time limit for such a retest.

SOME CATTLE REACT TO THE INTRADERMAL TEST BUT NOT TO THE THERMAL

For some reason certain cattle will react to one tuberculin test and not to the other.

Cow No. 7.
Dec. 12, tested thermally, negative reaction.
Dec. 22, tested intradermally, positive reaction.
Dec. 28, tested thermally, negative reaction.
Jan. 6, tested intradermally, positive reaction.
Apr. 29, tested intradermally, positive reaction.

Post-mortem examination showed extensive tuberculosis.

Cow No. 3.
Mar. 1, tested intradermally, positive reaction.
Mar. 3, tested thermally, negative reaction.
June 4, tested intradermally, positive reaction.
June 15, tested thermally, slight reaction.
June 28, tested intradermally, positive reaction.
July 1, tested thermally, negative reaction.

A post-mortem showed lesions of tuberculosis in the retropharyngeal and mediastinal lymph glands.

Cow No. 7, a generalized case of tuberculosis, gave no reaction to two thermal tests but reacted three times to the intradermal method. Cow No. 3 gave one slight reaction to the thermal test and twice gave no reaction at all. Three times, however, she gave characteristic reactions to the intradermal test.

We have also found instances where cattle react to the thermal test and not to the intradermal. In testing large numbers of cattle

no doubt many such individuals would be found. Both tests applied simultaneously to a herd should, in the great majority of cases, pick out all the tuberculous animals.

THE RELATIVE ACCURACY OF THE INTRADERMAL AND THERMAL METHODS

Investigators who worked with the intradermal test in former years, using the skin of the neck as a site for injection, found that 10 to 15 per cent of tuberculous animals did not react to the test. Later workers, using the caudal fold only, have found this method equal in accuracy to the thermal test. Luckey, Sheldon, Connaway, and others in Missouri, after testing many thousands of cattle, prefer the intradermal to the thermal. Haring and Bell of California find the two tests equal in accuracy and prefer the intradermal.

The question of the accuracy of either test does not lie in the condition of the animals condemned, as that is easily proved by post-mortem examination, but in the number of tuberculous cattle in the herd that did not react. There are plenty of figures to prove both tests better than 98 per cent accurate in the animals condemned, but there is a scarcity of figures to prove that the non-reactors are free from tuberculosis.

This needed information should be easily supplied for the intradermal test, as shipments of beef cattle can be tested and in a few days inspected on the killing floor of the abattoir.

Neither method is accurate except in the hands of a veterinarian or some experienced person, although the thermal test is more nearly mechanical and is used by a great many stockmen.

The following records show the comparative results of the two tests as applied to a few herds.

Dairy herd—36 grade cows.
  July 28, tested intradermally, no reactors.
  July 31, tested thermally, no reactors.

Dairy herd—21 grade cows.
  Aug. 5, tested intradermally, no reactors.
  Aug. 15, tested thermally, no reactors.

Dairy herd—11 grade cows.
  Feb. 5, tested thermally, 10 reactors.
  Aug. 19, tested intradermally, 10 reactors.

Post-mortem examination demonstrated that all these were tuberculous.

Dairy herd—16 Holsteins and Jerseys.
Aug. 8, tested intradermally, no reactors.
Aug. 11, tested thermally, no reactors.
Dairy herd—126 Holsteins and Guernseys.
Aug. 19, tested thermally, 30 reactors, 2 suspects.
Oct. 12, tested intradermally, 30 reactors, no suspects.

The intradermal test was applied only to the 32 head picked out by the thermal test. The reactors were killed and found tuberculous.

Dairy herd—16 grade cows.
Sept. 1, tested intradermally, 1 reactor.
Sept. 3, tested thermally, 1 reactor.

This animal was slaughtered and found tuberculous.

Dairy herd—26 grade cows.
Sept. 6, tested intradermally, no reactors.
Sept. 10, tested thermally, no reactors.
Dairy herd—12 grade cows.
Sept. 6, tested intradermally, no reactors.
Sept. 10, tested thermally, no reactors.
Dairy herd—11 grade cows.
Sept. 14, tested intradermally, no reactors.
Sept. 17, tested thermally, no reactors.
Dairy herd—21 grade cows.
Oct. 4, tested intradermally, no reactors.
Oct. 7, tested thermally, no reactors.
Dairy herd—9 grade cows.
Tested intradermally, no reactors.
Tested thermally, no reactors.
Dairy herd—38 Guernseys and Jerseys.
Dec. 28, tested intradermally, 2 reactors, 1 suspect.
Jan. 3, tested thermally, 2 reactors, no suspect.

These animals were slaughtered and found tuberculous.

Dairy herd—16 Holsteins.
Mar. 2, tested intradermally, 5 reactors.
Mar. 5, tested thermally, 4 reactors.

These four reactors were slaughtered and proved tuberculous. The cow reacting to the intradermal test and not to the thermal did not react to several subsequent tests.

Dairy herd—38 grade cows.
Mar. 14, tested intradermally, no reactors.
Mar. 17, tested thermally, no reactors.
Dairy herd—118 Holsteins.
Jan. 4, tested thermally, no reactors.
Apr. 20, tested intradermally, no reactors, 4 suspects.

In this test we used a special intradermal tuberculin. Subsequent thermal tests of these four animals gave no reaction.

Dairy herd—4 cows.
Apr. 24, tested thermally, 1 reactor.
May 10, tested intradermally, 1 reactor.
This animal was slaughtered and found tuberculous.

Dairy herd—12 grade cows.
May 12, tested intradermally, no reactors.
May 15, tested thermally, no reactors.

Dairy herd—22 grade cows.
May 12, tested intradermally, no reactors.
May 16, tested thermally, no reactors.

Dairy herd—17 grade cows.
May 13, tested intradermally, no reactors.
May 17, tested thermally, no reactors.

Dairy herd—26 grade cows.
May 22, tested intradermally, no reactors.
May 24, tested thermally, no reactors.

Dairy herd—36 grade cows.
May 23, tested intradermally, no reactors.
May 26, tested thermally, no reactors.

Dairy herd—16 grade cows.
May 29, tested intradermally, 1 reactor.
No retest. This animal was slaughtered and found tuberculous.

Dairy herd—5 grade cows.
June 22, tested intradermally, 1 reactor.
June 25, tested thermally, 1 reactor.
This cow was slaughtered and found tuberculous.

Dairy herd—22 grade cows.
Aug. 8, tested intradermally, 1 reactor (physical case).
Aug. 11, tested thermally, 1 reactor.
Post-mortem showed generalized tuberculosis.

Beef herd—11 bulls and cows.
Aug. 15, tested intradermally, 1 reactor, 2 suspects.
Aug. 16, tested thermally, 3 reactors.
Sept. 20, tested thermally, 3 reactors.
No post-mortem examination was made. In this case the local reaction to the intradermal test was undoubtedly modified by the subcutaneous injection made the following day.

Dairy herd—34 grade cows.
Sept. 12, tested intradermally, 1 reactor.
Sept. 15, tested thermally, 1 reactor.
Post-mortem of this cow showed lesions of tuberculosis.

Dairy herd—44 grade cows and calves.
Oct. 16, tested intradermally, 3 reactors.
Oct. 20, tested thermally, 3 reactors.

Dairy calves—7 Holsteins, 4 to 6 months.
Tested intradermally, 2 reactors.
Tested thermally, 2 reactors.

The thermal test cannot usually be depended upon with calves because of their uncertain range of temperature. Both these calves were found tuberculous on post-mortem.

Dairy herd—146 Holsteins.
Jan. 10, 1914, tested thermally, no reactors.
Jan. 12, 1915, tested intradermally, 1 reactor.

This cow was slaughtered and found tuberculous.

In a total of 909 cattle tested, 61 reacted to the intradermal test; 747 were retested with the subcutaneous or thermal test and 59 reacted. With the exception of 3 these were all destroyed and all found tuberculous on post-mortem.

Of range cattle, 1,726 head were tested and 1,420 retested, and a total of 111 reactors taken out. These were all destroyed, and with the exception of one animal all were found tuberculous.

In all, we have applied the intradermal test 4,055 times to 2,635 cattle, there being 1,420 retests made by this method. One hundred and seventy-two cattle reacted; 169 of these were slaughtered and 168 were found tuberculous on post-mortem examination. We consider this as reliable as the results of thermal tests, and except in a very few cases there was no doubt at all as to the reaction.

TESTING CALVES

It is well known that the very uncertain temperature range of a calf under six months of age makes a diagnosis by the subcutaneous test almost impossible.

We have not determined the earliest age at which a calf will react to the intradermal test but can see no reason why there should not be a reaction whenever a calf is tuberculous. Typical reactions have been obtained at four months (fig. 17) and it is probable that the reaction would be as typical in younger animals.

TESTING RANGE CATTLE

A well established but erroneous impression exists that range herds are practically free from tuberculosis. This has been accepted mainly because very few range herds have been tested, as it has been practically impossible to apply the thermal test to such animals.

If a range cow could be tied up or confined so that enough temperatures could be taken for the thermal test, she would be in such a state of excitement that the record would mean nothing.

With a corral, a chute, and some sort of a "squeeze," one man and a helper can test range cattle accurately at the rate of about 200 a day for an indefinite period. With a well built chute, such as is shown in figure 20, and plenty of well arranged corrals, one man and five or six competent assistants can test 500 to 600 cattle in a day. This means, of course, that 1,000 to 1,200 are handled each day, for each animal must go through the chute twice,—first for injection of tuberculin and again for observation of the reaction. With such an equipment we have tested frequently at the rate of

FIG. 20. A very serviceable type of chute. Range cattle can be tested rapidly and safely by this method.

150 cattle an hour for two or three hours at a time. However, it is seldom practical to test more than 400 or 500 cattle a day, because they must be kept in small pastures or in corrals and fed for three days, waiting for inspection, and by the third day there will be 1,200 to 1,500 to look after.

In working with a good "squeeze," accurate placing of the tuberculin is made easy. The cow is held motionless, the tail is

raised by an assistant, and the operator is free to clean the site of injection and make the injection in a careful manner. We have found that in testing animals in the chute the injection should be made, if possible, into the left caudal fold and from the left side of the cow. If the operator attempts to use the position advocated for dairy cattle, there is danger of having the arm seriously hurt by being pinched between the cow and the chute. It is also best to have a light cord attached to the syringe and around the wrist to prevent the instrument from being dropped under the feet of the cattle where it would inevitably be broken.

In observing the reactions on the third day, we have not found it necessary to use the "squeeze." Let the chute be crowded full of cattle and they will hold each other in place so that the tail of each can be raised, adequate observation made, and the whole chuteful released at once.

Reacting cattle should at once be branded conspicuously. We found it a help to "bob" the tail, cutting the brush or tassel squarely across. It is seldom possible to cut the reactors out of the herd until after the test, and the "bobbed" tail readily identifies them.

Though this State requires the tuberculin testing of dairy cattle brought in from outside, it has not required the testing of cattle brought in as feeders because the thermal test could not be applied to them. Tuberculosis in dairy cattle in Montana is well under control, about 3 per cent of those tested in 1914 reacting. Unscrupulous dealers, however, take advantage of the fact that feeders are not tested and ship in dairy cattle from eastern states as feeders or range cattle, eventually selling them as dairy cows. This system will continually bring in tuberculous animals. By the use of the intradermal test this loophole can be stopped, questionable shipments tested, and the State kept practically free from tuberculosis.

State-wide testing of range cattle may never be adopted, nor even thought advisable, for, as stated before, there is a firmly established impression among stockmen of the entire Northwest that there is no tuberculosis among such cattle. The following herds of range cattle, which were all we had an opportunity to test, were certainly not free from tuberculosis.

Herd No. 1.—216 Hereford cows, a few spayed heifers, and calves. Tested intradermally, with chute and "squeeze." Five

reactors. On post-mortem these were all found tuberculous.

Herd No. 2.—1120 range Shorthorn cattle, cows with calves at the side, steers, and spayed heifers. Tested intradermally, with chute and "squeeze." 86 reactors. On post-mortem these were all found tuberculous except one,—a yearling heifer.

On retest six months later, 7 cattle reacted and were destroyed. These were also found tuberculous on post-mortem.

Herd No. 3.—88 Shorthorn bulls, yearlings and two-year-olds. Tested intradermally, with chute and "squeeze." 6 reactors. On post-mortem these were all found to be tuberculous.

On retest six months later, 2 reactors were found, destroyed, and proved tuberculous.

Herd No. 4.—302 Hereford heifers, yearlings and two-year-olds. Tested intradermally, with chute and "squeeze." 5 reactors. On post-mortem these were found tuberculous.

It will be noticed that the Shorthorn range cows of herd No. 2 had a total of 93 reactors. These were typical range cattle, not cared for or given any shelter except brush, etc. They were fed hay for a short time in the winter. The infection was directly traceable to a shipment of bulls received five years previous to the test. This would seem to vitiate the argument that if tuberculosis did exist among range cattle, it would not be easily disseminated through a herd.

THE INTRADERMAL TEST FOR INTERSTATE SHIPMENTS

The objection to the intradermal method as an official test that is most frequently advanced, is that it leaves no record. As a matter of fact, it leaves more record on the cow than does the thermal test. The local tuberculin reaction usually leaves a hard lump or knot in the caudal fold which is persistent for two or three weeks or longer. Also, a subsequent subcutaneous injection frequently causes the site of the former local reaction to swell to nearly its original size.

As for the health certificate, however, that is a matter that is up to the personal honesty of the veterinarian. The present test chart, over the veterinarian's signature, is as easily falsified as a record stating the size and character of the intradermal reaction. If a veterinarian would state falsely, on his certificate of health, that there were no reactions to an intradermal test on certain cows, he would with as little compunction fix up a tuberculin test chart to pass those same animals.

ADVANTAGES OF THE INTRADERMAL METHOD

To one who has used both tuberculin tests, the following are a few of the advantages that make the intradermal test obviously preferable.

From the viewpoint of the cattle owner:

- The routine of farm work is not interrupted.
- The cattle are handled only twice.
- Cattle are fed and watered at the usual hour.
- There is no loss of milk as cattle have no occasion to get excited.

From the viewpoint of the veterinarian:

- It eliminates all late-at-night and early-morning testing.
- The test is elastic. Ordinary testing can be made to fit into the intervals of a busy practice.
- It largely eliminates misunderstanding and opposition on the part of the cattle owner, the arguments formerly brought forward to explain a rise of temperature in the thermal test having no bearing on the local reaction.

As an official test:

- State inspectors can test three times as many cattle as by the thermal method.
- Expenditures for thermometers and tuberculin are cut to a minimum.
- Retests on herds can be conducted in ten days after the first test, as against thirty days by the thermal method.
- Where a check test is desired, the subcutaneous test can be applied simultaneously with the intradermal or immediately afterward.
- Range cattle can be tested as rapidly and accurately as dairy cattle.

DISADVANTAGES OF THE INTRADERMAL METHOD

The test should cover seventy-two hours. If there is need for a hurried test, the thermal or subcutaneous method should be employed.

If the operator is unskilled, there is greater chance for error with the intradermal test than with the thermal.

SUMMARY

As a result of the foregoing work with the intradermal tuberculin test, we feel justified in the following conclusions:

1. The intradermal test for tuberculosis is equal in accuracy to the thermal test.

2. The ordinary tuberculin distributed by the U. S. Bureau of Animal Industry for thermal testing is preferable to any other for intradermal testing.

3. The intradermal test, in economy of time, labor, and expense, is preferable to the thermal test.

4. The intradermal test is especially valuable in the testing of herds of range cattle.

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EXPERIMENT STATION
F. B. LINFIELD, Director

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Thinning Experiments with Potatoes

A Preliminary Report

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BOZEMAN, MONTANA

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THE MONTANA EXPERIMENT STATION,
Bozeman Montana

Thinning Experiments with Potatoes

No doubt many of those who have had experience in digging potatoes with a fork have observed that the number, size and uniformity of tubers in any particular hill vary with the number of stems of plants in that hill. While hills with single stems do not produce a large number of tubers, the tubers are more uniform in size, and often more uniform in shape. With an increase in the number of stems in the hill there are more small potatoes, there is a greater variation in size, and the average weight of tubers is reduced. Though we may not always appreciate the fact, the quality of the crop, then, is determined somewhat by the number of stems developed in the hills. On the other hand, it is probably true that planting practices may have some influence upon the number of plants produced in hills. The planting of whole seed or large pieces of seed with several eyes may under some conditions tend to increase the number of stems per hill. While planting seed pieces bearing single eyes does not necessarily give hills with single plants (each eye may produce two, three, or even more stems), we would naturally expect that cutting to single eyes would reduce the number of double and triple stem hills. The planting of dormant seed (seed from good storage which has as yet shown no tendency to develop sprouts) is thought to produce hills with more stems than planting tubers which have begun to show some growth. If such is the case, no doubt a part of the benefits derived from "starting" or "greening" seed before planting is due to the fact that such a practice tends to reduce the number of stems in a hill.

The experiments here recorded were first suggested by work attempted in hill selection. It was thought that hills with a uniform number of stems would furnish a much better basis for selection. Searching for hills with single stems is, in the average field, tedious work, so it was decided to try thinning as a means of securing hills with a uniform number of plants. It was then noticed that thinning

modified the crop and it seemed worth while to test out the practice in growing potatoes for market. While the work covers only two seasons and the results are not conclusive, it seems desirable to call attention to the possibilities along this line that others may determine under their own conditions what benefits may be derived from such a practice.

METHODS

In these tests the comparisons cited, unless otherwise noted, are in each case from adjacent rows, each row containing from one-tenth to one-twentieth of an acre. Outside rows have always been eliminated and it would seem that the probability of errors has been reduced to the minimum. The land used has been in some cases old grain land and in other cases clover sod, but the yields that are compared are always from the same type of soil. The soil at the home station is rather heavy and black and would not be considered good potato land. The soil at the Fergus County substation is rather gravelly but contains so much clay that tools do not scour well. The irrigated potatoes were planted in rows 3 feet 9 inches apart. They received deep cultivation and were well ridged before irrigating. Each year the plots received one irrigation just after the potatoes were set, or, with most varieties, just about blooming time. The dates of irrigation were July 22nd, 1913, and August 2nd, 1914. The non-irrigated potatoes were planted in rows 3½ feet apart and, unless otherwise noted, received level cultivation. The crops were planted May 26-27, 1913, and May 23-25, 1914, and the tops were killed by frost September 22, 1913, and September 9, 1914. No effort was made to start the seed, and when planted the tubers of most varieties were quite dormant. The seed was cut into pieces as nearly two ounces in weight as possible with little reference to the number of eyes, although effort was made to reduce the number of eyes in the seed end pieces by cutting the tuber from end to end. In 1913 the thinning was done the first week in July. This was as early as the plants could be pulled without the stems breaking. In 1914 the thinning was done July 15th. This was really late and it is probable that this one factor accounts for the poorer results in this season's tests. Thinning consisted in pulling out of each hill

all but the strongest plant. One man could thin an acre a day. The potatoes were graded over a standard 1⅞-inch mesh screen.

RESULTS

The results of the work in 1913 are shown in Table I. The most noticeable benefit derived from thinning was the decrease in the amount of culls. In most cases the total yield was greatest from unthinned rows. It is also true that in most cases the yield of marketable tubers was greatest from unthinned rows, but the quality of the crop, so far as size and uniformity were concerned, was much better from the thinned rows. The greatest benefit was secured with the non-irrigated potatoes.

The results of the work at the home station in 1914 are shown in Table II. Again a noticeable result is the decrease in the amount of culls in thinned rows. It is quite apparent that thinning not only decreased the total yield but also the yield of marketable tubers. As before mentioned, this may be the result of late thinning. The quality of the marketable crop was greatly improved by thinning. Russet Burbank dropped 16 inches apart in the row, when thinned, produced marketable tubers averaging 8.3 ounces in weight, and when unthinned, marketable tubers averaging 5.1 ounces. Rural planted 14 inches apart and thinned produced mar-

1. **Russet Burbank dropped 12 inches apart and thinned. Yield per acre: Marketable 11,270 pounds, culls 680 pounds.**

2. **Russet Burbank dropped 12 inches apart and unthinned. Yield per acre: Marketable 13,550 pounds, culls 3,160 pounds.**

3. **Russet Burbank dropped 14 inches apart and thinned. Yield per acre: Marketable 10,840 pounds, culls 720 pounds.**

ketable tubers averaging 7.4 ounces, while in unthinned rows the marketable tubers averaged 6 ounces in weight. Russet Burbank planted 12 inches apart and thinned produced marketable tubers with an average weight of 7.5 ounces, and unthinned rows, marketable tubers averaging 5.3 ounces. This variation in the quality of the crop from thinned and unthinned rows is well shown in the illustration.

The results of one year's work at the Fergus County substation are shown in Table III. In most cases thinning increased the yield of marketable tubers and also the total yield. The quality of the marketable crop was greatly improved by thinning, the size and shape of tubers being much better from the thinned rows. These comparisons are reported from tenth-acre plots and not from adjacent rows.

SUMMARY

To be able to make a just comparison between hills, in searching for high yielding strains, it would seem important that these hills have a uniform number of stems, and those who are working with the hill selection method of seed improvement will find thinning one of the simplest means of securing uniform hills.

In growing potatoes for special trade where either large size or uniformity in size is important, thinning will be found to give good results. Even in growing potatoes for the general market, it may be found profitable to drop the seed closer in the row and thin to one plant in a place. The thinning will surely improve the quality of the crop and the close planting may give as large, if not larger, yields than greater distances of planting without thinning.

This system of thinning will without doubt prove of value in growing potatoes where irrigation water is not available and where drought is likely to catch the crop before maturity.

Further work is needed to determine the proper time to thin, and also the best distance for planting potatoes to be thinned.

That thinning modifies the crop, these tests, we believe, prove conclusively.

TABLE I—THINNING EXPERIMENTS WITH POTATOES, 1913

IRRIGATED

Variety	Distance of of planting (inches)	Yield per acre (pounds)					
		Marketable		Culls		Total	
		Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned
Early Rose	12	9,722	9,866	738	1,922	10,460	11,788
Russet Burbank	12	12,772	9.950	816	2,455	13,588	12,405
Russet Burbank	15.5	11,127	11,983	716	1,650	11,843	13,633
Burbank	12	9,483	10,100	663	1,117	10,146	11,217
Burbank	15.5	9,450	9,872	761	1,144	10,211	11,016
Rural	12	7,522	6,622	644	700	8,166	7,322
NON-IRRIGATED							
Early Michigan	15.5	6,084	5,440	783	2,212	6,867	7,652
Early Ohio	15.5	4,398	4,563	460	1,152	4,858	5,715
Russet Burbank	15.5	6,060	4,680	1,140	2,520	7,200	7,200

TABLE II—IRRIGATED POTATOES, 1914

Variety	Distance of of planting (inches)	Yield per acre (pounds)					
		Marketable		Culls		Total	
		Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned
White Early Ohio	14	6,872	7,707	1,030	1,698	7,902	9,405
Early Rose	14	6,988	10,510	512	2,642	7,500	13,152
Rural	14	10,257	14,436	449	1,030	10,706	15,466
Rural	14	7,700	11,350	454	1,260	8,154	12,610
Russet Burbank	14	10,840	15,190	720	2,700	11,560	17,890
Russet Burbank	14	11,836	15,662	363	1,801	12,199	17,463
Burbank	12	10,480	14,530	830	2,080	11,310	16,610
Rural	12	10,830	11,450	520	1,450	11,350	12,900
Russet Burbank	12	11,270	13,550	680	3,160	11,950	16,710
Russet Burbank	16	11,437	14,510	460	1,514	11,897	16,024

TABLE III—THINNING EXPERIMENTS WITH NON-IRRIGATED POTATOES

Fergus County Substation, 1914

Variety	Method of culture	Yield per acre (pounds)					
		Marketable		Culls		Total	
		Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned
Green Mountain......	Level	3,360	3,120	720	1,080	4,080	4,200
Green Mountain......	Ridge	3,264	2,760	636	960	3,900	3,720
Pink Eye....................	Level	4,164	3,720	840	1,116	5,004	4,836
Pink Eye....................	Ridge	3,864	4,080	480	840	4,344	4,920
Early Breakfast	Level	2,804	3,480	684	996	4,488	4,476
Early Breakfast	Ridge	3,444	3,084	540	840	3,984	3,924

Montana Agricultural College Experiment Station

F. B. LINFIELD, Director

BULLETIN No. 107

Corn in Montana

History, Characteristics, Adaptation

The corn, the corn, the yellow corn!
The red, the white, the blue!
The corn fields shall adorn
Our State, and make it new!
—From a Hunkpapa Indian song.
Translation by Dr. Beede.

BY
ALFRED ATKINSON
Agronomist
AND
M. L. WILSON
Assistant in Corn Investigations

BOZEMAN, MONTANA
October, 1915

MONTANA AGRICULTURAL COLLEGE EXPERIMENT STATION

BOZEMAN, MONTANA

NOTICE.—The Bulletins of the Experiment Station will be mailed free to any citizen of Montana on request. Please state whether all the publications are desired as issued or only those specified. Give name and address plainly. All communications to the Experiment Station should be addressed to

THE MONTANA EXPERIMENT STATION,
Bozeman Montana

Contents

FOREWORD

The census of 1899 showed 3,301 acres of corn in Montana with a total yield of 75,838 bushels. In 1909 this had increased to 9,514 acres with a yield of 274,100 bushels or an increase in the ten-year period of 188 per cent.

During the past five years much more attention has been given to this crop, so that the area planted to corn has grown rapidly. The following figures are taken from the Yearbooks of the U. S. Department of Agriculture except the figures for 1915 which are taken from the November Crop Report of the Bureau of Crop Estimates of the U. S. Department of Agriculture.

AREA AND YIELD OF CORN IN MONTANA FOR THE YEARS 1910-1915

Year	Acres	Total yield (bushels)
1910	16,000	368,000
1911	20,000	530,000
1912	24,000	612,000
1913	28,000	679,000
1914	50,000	1,064,000
1915	70,000	1,960,000

This shows an increase of 736 per cent in area and of 715 per cent in the total corn crop in the six years as compared with the 1909 report. The yield of 2~~0~~8 bushels per acre for the 1915 crop compares not unfavorably with districts usually considered very much better adapted to corn growing.

The facts given above have a very important relation to the agricultural development of the State and particularly to the dry farming areas of eastern Montana.

Corn provides an intertilled or cleaning crop,—something very much needed in the agricultural practice of all parts of the State. To a large extent it also takes the place of a summer fallow, thus materially reducing the cost of crop growing on the dry farm. Further, it provides a large forage crop and thus encourages the keeping of live stock and promotes diversified farming, all of which helps to build a safer and more permanent agriculture.

The Experiment Station is doing all it can to help forward the development of this crop by improving the varieties and adapting them to larger areas. The work recorded in this bulletin has laid the foundation for much future study in this direction. The observations so far made lead us to believe that the corn crop will play a very important part in the future agriculture of the State.

The authors of this bulletin are both from the corn belt and for a number of years were assistants in the corn investigations and agricultural extension work of the Iowa Agricultural College. Thus they brought to this problem first-hand experience and knowledge of corn and of the best methods of handling and growing the crop. Several years' study of the climate, soil, and crop conditions ot Montana has given them very full information as to its corn-growing possibilities.

The project which furnished the data in this bulletin was started in the summer of 1910, when Mr. M. L. Wilson joined the station staff as assistant in the agronomy department. For some four years he was in charge of the experiment and demonstration farms of eastern Montana. The data presented were gathered during this period and have been compiled and prepared for publication within the past few months. During the past year Mr. Wilson has been made State Leader of County Agriculturists and so is no longer connected with the Experiment Station.

F. B. Linfield,
Director.

ACKNOWLEDGMENTS

For making available historical and other material which has been of substantial assistance, the authors are indebted to the following men: George F. Will, of Bismarck, North Dakota, who has been a careful, painstaking student of Indian corn, both from an agronomic and an ethnological standpoint, and whose researches, published by the Peabody Museum of Harvard University, are among the most valuable American Indian studies; Rev. Gilbert L. Wilson, of Minneapolis, through the kindness of the American Museum of Natural History and the University of Minnesota, for the results of studies of Hidatsa corn; Charles E. Brown, of the Wisconsin State Museum, Madison, for information regarding the North Central Indians; Arthur C. Parker, of the New York State Museum, for assistance in procuring information about New England corns; H. C. Fish, curator of the State Historical Society of North Dakota, for material on Indian corn culture in that State; Oscar H. Will, of Bismarck, North Dakota, a pioneer in the development of Northwestern corns; Edgar Gregory, of Marblehead, Massachusetts, for information about early New England corns; C. C. Massey, of Northrup, King & Company of Minneapolis, for information given; Dr. A. McGaffne Beede for permission to use the verse on the cover page, which is a literal translation of a Hunkpapa Indian song; L. C. Burnett, of the Iowa Experiment Station, for data on the leaf area of Iowa corns; J. C. Taylor for assistance in the corn tests; and W. O. Whitcomb for drawings furnished.

Corn in Montana

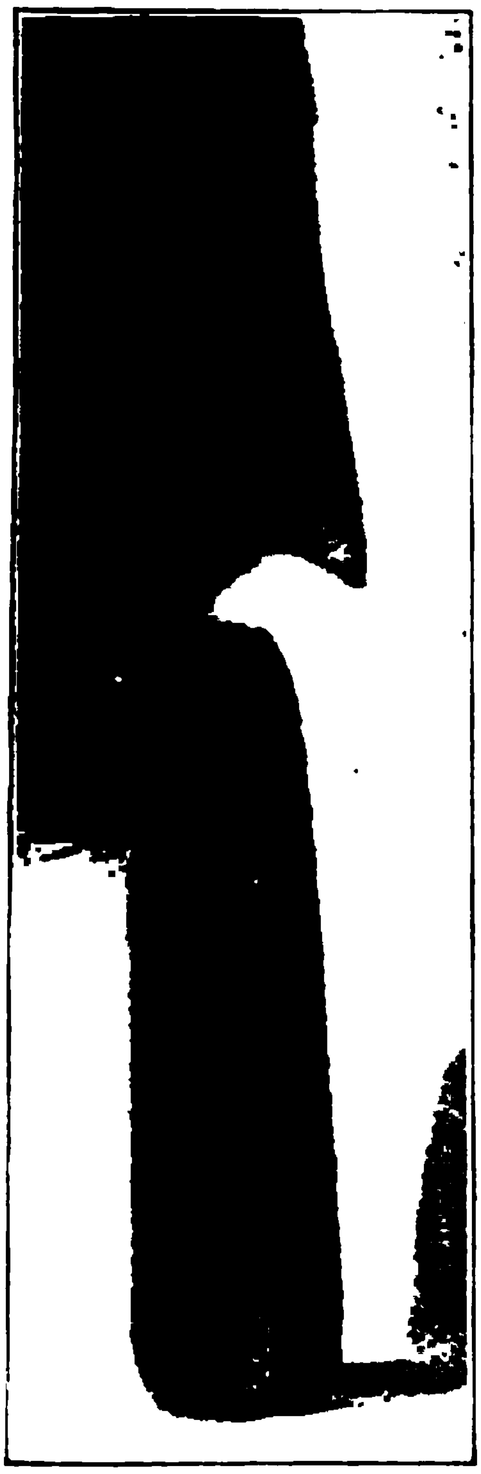

FIG. 2. Prize ear.*

This bulletin has been prepared for the purpose of showing that certain types of corn may be grown in most localities of Montana, and for the further purpose of giving the reasons for the authors' belief that the corn crop is destined to occupy an important place in Montana's agriculture.

The material is divided into five distinct parts. Part I deals with the economic position of the corn crop in the leading agricultural states and points out the relationship which this crop is almost certain to have to the agriculture of the Northwest. Part II presents historical material which establishes the fact that certain types of corn have long been grown by American Indians and white settlers in regions considerably north of the so-called corn belt of the United States, and further shows that this Indian corn culture was of a high type and that there have resulted from it certain groups and varieties of corn adapted for growth in Montana. Part III deals with the classification and description of the most promising corn varieties of the Northwest. Part IV discusses the temperature, moisture, and other climatic factors which are important in determining the corn-growing possibilities of any region. In Part V are presented data from investigations conducted in 1913 and 1914 which show wherein corns adapted to Northwestern conditions differ from the corn belt types.

* Prize-winning single ear, Eastern Montana Corn Exposition, Miles City, 1914. Exhibited by Mr. Leon B. Clark, Prairie County, Montana.

Part I. Economic

THE ECONOMICS OF THE CROP

Corn is more distinctively American than any other of our farm crops. Not only did it originate in America and furnish the chief vegetable food of the natives, but it is today the leading crop of the nation. According to the 1910 census, "for each dollar the farmer of this nation receives for grain, either directly or indirectly, fifty-four cents comes from corn." Probably no other one factor has influenced American agriculture more than corn growing. Carver* has pointed out that it is the greatest single industry of the nation. "Its culture maintains a larger number of our people than any other industry and no other American product or group of products equals it in value."

Agricultural wealth is greatest in the corn states. No doubt this is due to the fact that corn produces more digestible nutrients per acre than any other non-intensive crop, and that 78 per cent of the grain is fed to live stock upon the farm which produced it. Thereby a concentrated food product is obtained with a minimum loss in fertility.

Corn not only yields a crop of grain but a crop of fodder at the same time. No crop makes better silage, and the relation of silage to dairying is now pretty well established. When fed in a properly balanced ration, corn produces very economical pork, beef, or mutton. Properly cured corn stover is equal to timothy for feeding idle horses and some other classes of live stock. The profits of corn rest not alone on the crop, for when small grain is planted on clean corn stubble, the yield is nearly as great as on summer-tilled land. It is also a common observation that in a dry year, corn, when thoroughly and frequently cultivated, withstands drought better than the small grains.

The corn-growing states are the home of the very happy and prosperous agricultural people. Corn-raising does not lend itself to bonanza farming or extensive engine methods. The farms are of medium size, ranging from a quarter-section to "three eighties," and the work is mostly done by the farmer and his family, with the occasional assistance of a hired man. There are no rush periods

* Carver, T. N. The Corn-Growers. In World's Work, vol. 7, p. 4127.

requiring irresponsible itinerant labor, and the slack winter months are occupied by feeding the crop to hogs and steers. Carver has pointed out that this type of farming is productive of desirable social and economic conditions. He says,* "The corn belt is the most considerable area in the world where agriculture is uniformly prosperous. This prosperity is, moreover, healthful and natural, and not artificial, like the sugar beet industry, for example, which has never in any country shown its ability to stand alone unaided by government favors, nor, like much of our manufacturing prosperity, based upon government protection. The people engaged in the corn-growing industry are an independent, progressive class, drawing their sustenance from the soil, and not from other people."

NORTHWESTWARD CORN MOVEMENT

Corn has been gradually moving northwestward for the last half century. Horace Greeley, the editor who advised young men to go west and grow up with the country, recognized that corn was going west also. In 1871 he wrote,** "Though Wheat-culture still recedes before the footsteps of advancing population, and Minnesota may soon cease to grow for others, as Western New-York, Ohio, Indiana and Northern Illinois, have already done, yet Indian Corn, being the basis of both Beef and Pork, will long hold its own in the Valley of the Ohio and in that of the Upper Mississippi. As it recedes slowly Westward, Clover and Timothy, Butter and Cheese, will press closely on its footsteps." The pioneer crops of all localities in the Northwest have been flax and wheat. Many difficulties accompany the raising of these crops exclusively and gradually they have given way to corn. The fundamental principles of crop rotation and the need for diversified farming, together with the food requirements of livestock, have brought about this change from flax and wheat to corn.*** This is no doubt a natural evolution as flax and

* Carver, T. N. Life in the Corn Belt. In World's Work, vol. 7, p. 4239.

** What I Know of Farming: A Series of Brief and Plain Expositions of Practical Agriculture as an Art Based upon Science, p. 37. New York, G. W. Carleton & Co., 1871.

*** This evolution is well treated by John G. Thompson in Rise and Decline of Wheat Growing Industry in Wisconsin, University of Wisconsin Bul. 292, and by Benj. H. Hibbard in The History of Agriculture in Dane County, Wisconsin, University of Wisconsin Bul. 101.

wheat are well adapted to fertile prairie soils which are free from injurious weeds and destructive diseases.

The early settlers in the prairie and northwestern states have always been in doubt about raising corn. The first settlements in Illinois were made along the streams and next to the timber, as the prairies at this time were considered of doubtful value. The first settlements in Iowa were in the southern and central parts and the first newspapers express doubts as to whether there would ever be much corn raised in the northern part of the state. Table I clearly illustrates this northwestward movement of the great crop.

TABLE I. SHOWING THE ACREAGE OF CORN IN THE NORTHWESTERN STATES FOR THE THIRTY YEARS ENDING WITH 1909

(From Thirteenth U. S. Census, V, 582)

Year	Minnesota	North Dakota	South Dakota	Montana
1879	438,737	....	*90,852	197
1889	901,690	11,954	753,309	1,019
1899	1,441,580	62,373	1,196,381	3,301
1909	2,004,068	185,122	2,037,658	9,514

* Includes North Dakota. At that time the territory had not been divided.

Robinson* says of the northern movement of corn in Minnesota, "Corn continued to spread northward during the decade (1899-1909). The area of greatest density, which in 1899 was limited to the southern tier of counties, by 1909 had advanced at least two tiers of counties, extending well toward the headwaters of the Minnesota. Moreover, the Squaw and Flint varieties characteristic of frontier agriculture had largely given way to the more productive Dent corn. In fact, it may fairly be claimed that corn has completed the conquest of the State, aside from the north shore of Lake Superior; since, according to the census of 1910, corn of some sort was grown in every county but two. It however remains to be determined how far north corn is likely to become a commercially important crop."

Wheeler** states, "Corn occupies a place in northwestern agri-

* Robinson, Edward Van Dyke. Early Economic Conditions and the Development of Agriculture in Minnesota. Studies in the Social Sciences, No. 3, p. 176. University of Minnesota, 1915.

** Wheeler, W. A. Corn Culture in the Northwest. Mitchell, South Dakota, 1913.

culture entirely distinct from that of the middle states. In many of the drier sections, corn is grown to take the place of summer fallow. . . . As the summer fallow is not a good economic proposition because of leaving the land idle for one year, corn occupies a good place as a substitute for summer fallow. Looked upon in this light corn proves a profitable crop in many sections of the northwest where it might not be considered profitable when looked at solely from the point of actual production of marketable ear corn. There are very few localities where fodder corn or ensilage cannot be used to advantage for feed for live stock of some kind. The greatest aid to corn growing in the northwest will be the introduction and development of suitable varieties."

The results of careful and extended research made by the Office of Dry-Land Agriculture are clearly in line with the foregoing statement. This office reports* that with spring wheat—and the same results essentially were obtained with spring barley and with oats—"disked corn ground has given consistently high yields. This, together with the low cost of preparation, has resulted in its showing the highest average profit or lowest average loss of any of the methods tried at all of the fourteen stations except one. These profits are based on the assumption that the corn crop was so utilized as to pay for the cost of its production."

In a summary of their investigations up to 1915 the same office further states** in regard to the profits of the corn crop itself, not taking into consideration the benefits to the succeeding crop, that "when a value of $4 per ton is assigned to the fodder, corn has been profitably grown by some method at all but one of the stations."

MONTANA CORN PROBLEMS

According to data secured from dry land investigations conducted by this experiment station, there are in the neighborhood of 18,000,000 acres of land in Montana adapted to some form of corn raising. This area is equal to three-fourths of the combined corn acreage of Iowa and Illinois. Climatic conditions in Montana are entirely different from those in the Middle West, and conse-

* Chilcott, Cole and Burr. Spring Wheat in the Great Plains Area. U. S. Dept. Agr. Bul. 214, p. 43.

** Chilcott, Cole and Burr. Corn in the Great Plains Area. U. S. Dept. Agr. Bul. 219, p. 31.

quently the varieties of corn and methods of growing, harvesting, and utilizing it must be different.

The chief source of income on most dry land farms at present is from grain sold. This has certain serious disadvantages. If the crop of grain is poor or the price is low the farmer does not prosper. Another disadvantage is the unequal distribution of labor—the rush at periods of seeding and harvesting with but little to do in the intervening time. The land must be plowed for each grain crop and in the drier sections there must be an occasional summer season of light moisture demand. This is usually provided by summer fallowing. Corn growing changes this type of farming to a diversified basis. Instead of being limited to one source of income, the farmer has a number, such as pork, beef, and dairy products, in addition to grain.

Within the last decade a transition has taken place from free range to land ownership and grain raising. This has completely demoralized the old type of stock production and a new type must be developed. Probably not more than half the area of Montana outside of the forests and mountains can be classed as tillable land. The remainder is rough, broken, or in bad lands, but affords very rich pasturage when not overstocked. The stock industry which will be built up in the future will utilize these rougher lands for grazing during a portion of the year and will depend on roughage, produced upon the dry farm, during the remainder. These conditions require a cheap form of roughage and, next to alfalfa, nothing can compare with corn.

Experiments conducted by this station and the experience of many farmers throughout the State have established beyond any possible doubt that corn can be profitably grown. There are five reasons why it should be grown and why in the future it will be of great importance in Montana.

1. The corn crop, where thoroughly cultivated and kept free from weeds, makes possible the preparation of a seed bed for small grains almost, if not quite, equal to summer-tilled land.
2. Corn has a low moisture requirement and in a dry year will produce a more profitable crop than small grains.
3. The raising of corn leads to the keeping of live stock upon the farm, especially hogs.

4. Corn produces a cheap and profitable roughage to be used in combination with the grazing lands.

5. Corn provides the carbohydrates to balance the proteins of alfalfa.

The Office of Dry-Land Agriculture*, in discussing the place of corn in the agricultural economy of the regions of light rainfall, says:

"Experience had shown that in the production of fodder it was at least as safe a crop, and perhaps as productive, as any that could be grown in a large part of the area. Experience had also shown that corn growing possessed merit as a preparation of the land for a crop of small grain. When these two factors are combined in one crop they make its growth of double importance. Corn is the only crop at present available that offers this advantage which at the same time lends itself to large acreage and a general farming system.

. . . . .

"Potatoes have approximately the same effect as corn upon most crops that may follow them, but the potato crop does not lend itself so well to growth on a large acreage."

* U. S. Dept. Agr. Bul. 219, p. 1.

Part II. Historical

It is very generally believed that profitable corn production in the central and western United States will always be confined to the valleys of the Ohio, central Mississippi and lower Missouri rivers. A study of corn growing by the Indians in the northern portion of the United States and in southern Canada shows that the corn crop has long been cultivated there and was one of their chief sources of food supply. The discussion in this part of the bulletin shows the important place which corn held among the tribes north of the so-called corn belt.

ORIGIN OF CORN

All authorities are practically agreed that corn is of hybrid origin and a native of some part of Mexico. It is probable that in comparison with wheat this crop is of somewhat recent origin and, therefore, not as fixed in its character as those that have been longer established. Few crops show adaptability to so wide a range of conditions as corn. Some varieties mature in eighty days and some require two hundred days. With this adaptability it is reasonable to assume that the limits of possible corn culture are as yet unknown.

During the pre-Columbian period in North America, corn was widely disseminated. Mooney, of the Bureau of American Ethnology, in a personal letter to the authors, concludes that "corn was cultivated by practically all the tribes of the forest region east of the Plains area, northward to the limit of successful cultivation somewhat north of the line of the Great Lakes and St. Lawrence. It was probably not cultivated on the Plains except by the Hidatsa, the Arikara and Mandan tribes of North Dakota, and the Pawnee and Omaha tribes in Nebraska. It was cultivated also by all the Pueblo, the Navaho and all the other tribes in the southwest."

Harshberger* has presented proof that its dissemination took place many centuries ago and that corn is found in most of the archeological remains in the northern part of the United States.

* Harshberger, John W. Maize: A Botanical and Economic Study. University of Pennsylvania. 1893. This is a very important contribution to the literature bearing on the history of corn.

Cyrus Thomas,* of the Bureau of American Ethnology, has summarized the distribution and economic importance of the Indians' corn culture as follows:

"Harshberger says linguistic evidence shows that maize was introduced into the United States from the tribes of Mexico and from the Carib of the West Indies, but the time of this introduction can only be conjectured. That it was long before the appearance of Europeans, however, is evident, not only from its early and widespread cultivation by tribes of the area now embraced in the United States, but from the fact that indications of its cultivation are found in mounds and in the ancient pueblo ruins and cliff dwellings, while corroborative evidence is found in the fact that several varieties of maize had already been developed at the time of discovery. . . . Jacques Cartier, the first European to enter the St. Lawrence, observed large fields of growing maize at Hochelaga (now Montreal) in 1534, and Champlain in 1604 found it in cultivation at almost every point visited from Nova Scotia to upper Ottawa river. The supplies of maize obtained from the Indians by the New England and Virginia colonists are well known. Hennepin, Marquette, Joliet, LaSalle, and other early French explorers of the Mississippi valley found all the tribes they visited, from the Minnesota river to the Gulf, and even into Texas, cultivating maize; and the same was true of the tribes between northwest Mexico and the plains of Kansas when visited by Coronado in 1540-42. Even the Mandan and Arikara on the upper Missouri had their maize patches when first seen by the whites. How far northward on the Pacific slope the cultivation of maize had extended at the time of the discovery is not known. . . .

"The ease with which maize can be cultivated and conserved, and its bountiful yield, caused its rapid extension among the Indians after it first came into use. With the exception of better tillage the method of cultivation is much the same today among civilized men as among the natives. Thomas Hariot, who visited Virginia in 1586, says the Indians put four grains in a hill 'with care that they touch not one another.' The extent to which the cereal was cultivated in prehistoric times by the Indians may be inferred from these facts and from the observations of early explorers. It seems evident from the history of the expeditions of De Soto and Coronado (1540-42) that the Indians of the Gulf states and of the Pueblo region relied chiefly on maize for food. It is also probable that a moiety of the food supply of the Indians of Virginia and the Car-

* Handbook of American Indians. Bur. American Ethnology, Bul. 30, pt. 1, p. 790.

olinas, and of the Iroquois and Huron tribes, was from the cultivation of corn. Du Pratz says the Indians 'from the sea (Gulf) as far as the Illinois' make maize their principal subsistence. The amount of corn of the Iroquois destroyed by Denonville in 1687 has been estimated at more than a million bushels (Charlevoix, His. Nouv. France, II, 355, 1744), but this estimate is probably excessive. According to Tonti (French, Hist. Coll. La., I, 70, 1846), who took part in the expedition, the army was engaged seven days in cutting up the corn of four villages."

Therefore we must bear in mind that while corn had a southern origin it has had northern adaptation for a long period of time and it is incorrect to consider it as an essentially southern crop.

CORN GROWING OF NORTHEASTERN INDIANS

Two groups of Indians, the Algonquin and the Iroquois, lived along the northeastern coast and lake region of the United States. Their corn culture, when compared with that of the southern Indians, seems to have been quite superior, as the latter had only four varieties of corn and did not develop the possibilities as much as their climatic conditions would warrant.*

The Iroquois were a very intelligent group and developed a remarkable corn culture. The following is summarized from Mr. Arthur C. Parker's scholarly paper on Iroquois corn:**

The Iroquois raised four varieties of soft or starchy corn, four of flint, two of sweet corn, two of pop corn, and one pod corn.

Fields were selected in clearings which were made by first girdling the trees and later burning them. The soil was dug up with wooden digging sticks and mellowed with either wooden or bone hoes. Trenches were made, five or six feet apart, and five or six kernels of corn dropped in each hill. The seed was soaked in warm water and sprouted prior to planting. In some cases the corn was soaked with hellebore roots, which made a poison for crows or other field pests that might eat the seed corn. Sometimes it was planted in April, but the bulk of the planting was done in May.

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* Bruce, Philip A. Economic History of Virginia in the Seventeenth Century. New York, The Macmillan Co., 1895.

** Iroquois Uses of Maize and Other Food Plants. New York State Museum Bul. 144. Albany, Univ. of State of N. Y., 1910. This is the most important single contribution on Indian corn which has been made within recent years. It is rich in history, citation, and Indian lore.

It was hoed twice, first when a span high—and at this time it was hilled up—and again when knee-high.

The corn was planted for many years on the same land, and as the soil weakened fish were added to the hills as fertilizer.

At harvest time the corn was snapped and thrown over the shoulder into a basket, or sometimes the stalks were pulled, but in every case the corn was taken to the house and later a husking bee was held. The seed corn was braided and hung up on cross beams of houses or other dry places. The bulk of the corn was stored in pits for future use.

The cosmic myths of the Iroquois are full of references to maize. In their social and ceremonial life they have also referred frequently to corn. These Iroquois corns formed the foundation stock of the varieties which were developed by the New England colonists. The New England farmers in colonial times did not make great progress in corn culture. Mrs. Alice Morse Earle in her interesting book, "Home Life in Colonial Days," mentions the facts that their soil was not exceptionally fertile, that in most cases the primitive woods had to be cleared, and that modern corn tools were not then available.

CORN GROWING OF THE NORTH CENTRAL INDIANS

Corn was cultivated by most of the Indian tribes of Wisconsin and Minnesota. The Ojibways, or Chippewas, who were of Algonquin stock, have always been northern Indians and came to Wisconsin and Minnesota from the St. Lawrence and Lake Huron region. They have always been corn raisers.*

In a letter to the authors, Mr. Lyman Ayer,** of Little Falls, Minnesota, says:

"When we moved to Red Lake, Beltiami County, Minnesota, latitude 48°, in 1854, I was ten years old. The Indians living there at that time were the Red Lake Chippewas or Ojibways. They were the most fore-handed of any band in their nation. They cultivated corn extensively. The corn cultivated by these Indians was a small,

* Upham, Warren. Minnesota in Three Centuries, vol. 1, p. 113. Publishing Society of Minnesota, 1908.

** Lyman Ayer's parents were missionaries among the Chippewas, starting their work with that tribe in 1854. Mr. Ayer is fully informed on most of the historical matters of this tribe.

eight-rowed variety, about six inches in length, generally known as Squaw corn; the color white and blue, in varying proportions in individual ears from all white to all blue, but usually mixed in the ear; occasionally red kernels, seldom a red ear, never yellow, either ear or kernel. The same corn is cultivated in that locality, and I am informed by the superintendent of the Agency farm that in 1910 they secured a yield of 92 bushels of shelled corn per acre.

"The methods of cultivation were crude and primitive. The ground was broken up and pulverized with a hoe bought from the traders. This tool was a cross between a hoe and a mattock, a heavy, clumsy implement, but effective when handled with sufficient vigor. A wooden hoe constructed from the branch of a tree was often used when short of other tools.

"It was the custom to sprout the seed before planting. This was usually done by placing a layer of moss in a large, flat tray made of birch bark, then spreading the seed corn evenly upon the moss and covering it with other layers of moss and saturating both layers with warm water. The trays containing the sprouting corn were kept in the wigwams when cold, but placed in the sun on fine days. The advantage of sprouting corn was that there was no loss from imperfect germination and a full stand was secured, and secondly, the growth is advanced thereby, at least a week or ten days, which is quite an item when the season is so short.

"The corn was cured by braiding or tying in bunches and hanging up on racks 10 feet high, constructed with crotches and poles. The more careful and industrious ones used to smoke the corn when hanging on the racks, claiming that it was thereby rendered more impervious to damage from moisture or insects. There appears to be some support to this idea, as after shelling, the corn is put into sacks made of cedar bark, holding about a bushel each, and then stored in a hole in the ground for months without damage.

"I am not sure as to the probable source of the Red Lake Chippewa corn. They came originally from Canada and the natural suggestion is that they brought their seed corn from there, but in the part of Canada from which they last removed, there is no corn raised. Knowing the Mandans used to raise corn on the Missouri River, it has seemed to me that probably the seed might have been secured from them. The Redlakes used to have communication with them."

Remains of the Wisconsin Indians show a wide dissemination of maize. The records of the Wisconsin Archeological Society show that it was grown everywhere from the southern State line north to the Lake Superior shore. Remains of corn-planting grounds are

found associated with mounds and village sites, and in many cases well defined corn fields and garden beds remain.*

UPPER MISSOURI INDIANS

One of the most interesting and remarkable facts in connection with Indian corn is that three tribes—the Hidatsa, the Arikara, and the Mandan—who lived along the Missouri River and its tributaries in North Dakota, were practicing a highly developed system of corn culture at the time of the first recorded visit of the white man in 1738. Archeological evidence secured from the Indian remains of this section indicates that corn was being raised in this district three or four hundred years ago. One would naturally expect the southern and eastern Indians to be good corn raisers, as they lived in regions of abundant rainfall and sufficient summer heat. It is really astonishing, however, that these upper Missouri Indians, living under semiarid and northern conditions, should develop corn raising to a point that was not surpassed by any other tribe in America.

This corn culture was of such importance that the early fur traders established a distillery in 1833 at Fort Union, which was located at the mouth of the Yellowstone River.** A letter in regard to this says, "The Mandan corn yields badly but makes a sweet liquor." Maximilian,*** Prince of Wied, speaks of large Mackinaw boats loading with Mandan corn for Fort Union.

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* Those who wish to pursue this further may find the subject fully treated by the following authors:

Brown, Chas. E. Archeological History of Wisconsin. In Wisconsin, Its History and Biography, v. 3, pp. 582, 583.

———— A Record of Wisconsin Antiquities. In Wisconsin Archeologist, v. 5, nos. 3 and 4.

———— Wisconsin Garden Beds. In Wisconsin Archeologist, v. 8, no. 3.

Hibbard, Benj. H. Indian Agriculture in Southern Wisconsin. In Proc. Wis. Hist. Soc., 1904, pp. 145-155.

Stickney, G. P. Use of Maize by Wisconsin Indians. In Parkman Club Publications, no. 13.

West, Geo. A. The Indian Authorship of Wisconsin Antiquities. In Wisconsin Archeologist, v. 6, no. 4.

** Chittenden, Hiram Martin. The American Fur Trade of the Far West, p. 358. New York, Francis P. Harper, 1902.

*** Early Western Travels, 1748-1846, edited by Reuben Gold Thwaites. Vol. 23, p. 211. Arthur H. Clark Co., 1906.

Since the Indians were the first dry-land farmers and corn raisers of the Northwest, Montana corn history naturally begins with them. Their corn was the last of the Indian corn to be adopted by the white man, and since the early flint group as discussed in this bulletin is directly derived from it, the methods of culture and the history are of much interest and importance.

THE ARIKARA

The Arikara are a branch of the southern plains tribes and are closely related to the Pawnee in Nebraska and the Wichita in Oklahoma. Some students think they were the first to raise corn on the upper Missouri, bringing it with them from a more southern home. They were known to the roving plains Sioux as the corn planters. Their seed selection was supervised by the medicine men.

Matthews,* who was an assistant surgeon in the United States Army, stationed at the military post at Fort Berthold in 1854, about forty miles up the river from where Bismarck now stands, says:

"The Arikarees and Mandans have doubtlessly tilled the soil for many centuries. Their accounts of the origin of corn are mingled with their earliest myths and traditions. There are some reasons for believing that the Arikarees represent an older race of farmers than the Mandans; for their religious ceremonies connected with planting are the more numerous. and they honor the corn with a specie of worship. In every Arikaree lodge, there is a large ear of corn, which has lasted for generations, sticking out of the mouth of a medicine bag. At their feasts they make offerings to the corn by rubbing a piece of meat on it, while they pray to it for plentiful harvests, and address it by the name of 'mother.' The Hidatsas claim to have had no knowledge of corn until they first ate it from the trenchers of the Mandans; and they have no important ceremonies connected with the harvesting, yet they cultivated it long before the advent of the white man."

Dr. Melvin R. Gilmore,** of the University of Nebraska, says that "the Arikara seem to have been the leading Indian farmers of the Missouri Valley. Omaha legend credits the Arikara with first having maize and the common pictograph sign for the Arikara

* Matthews, Washington. Ethnology and Philology of the Hidatsa Indians, p. 12. Government Printing Office, 1877.

** Letter to the authors. Dr. Gilmore is chief of the Nebraska State Historical Museum and has made extended researches into the agriculture of the plains tribes of Indians.

among the neighboring tribes was a conventionalized corn ear. In the sign language also the surrounding tribes designated the Arikara by a motion of the hands depicting the act of shelling corn, or by the motions of eating green corn from the ear."

Miss Alice C. Fletcher* comments that "as far back as their traditions go the Arikara have cultivated the soil, depending for their staple food supply on crops of corn, beans, squashes and pumpkins. . . . In the series of rites, which began in the early spring when the thunder first sounded, corn held a prominent place. . . . Rites were observed when the maize was planted, at certain stages of its growth, and when it was harvested."

THE MANDAN

Thus it seems probable that corn was borrowed from the Arikara by the Mandan, who in turn taught the Hidatsa its culture. The Mandan, however, were better farmers than the Arikara and developed a higher corn culture. Fortunately they were visited by a number of explorers, who have left us a fairly accurate picture. The first explorer to visit the Mandan was a Frenchman—M. de la Verendrye.** He speaks of their corn and storage pits in a brief journal written at the time of this exploration.

Next came Lewis and Clark, who spent the winter of 1804-5 in a camp near one of the Mandan villages. Heinemeyer*** says, "It is a known fact that the Lewis and Clark expedition was nearly destitute of food when it reached the territory which now comprises western Dakota, and unless they obtained food, they would have been compelled to retrace their steps and abandon further explorations. History substantiates the fact that from the Indians of this territory, they obtained enough corn for food to allow them to continue their journey."

* Handbook of American Indians. Bur. American Ethnology, Bul. 30, pt. 1, pp. 84, 85.

** The authors are indebted to Mr. George F. Will for the use of a typewritten copy of the Verendrye journal made from the Harvard University Library copy of the same.

*** Heinemeyer, C. E. When Corn Was King. A Historical Treatise of Corn Growing in North Dakota. Bismarck, North Dakota, 1914.

In the journal of the Lewis and Clark expedition* we find the following under date of November 22d, 1804: "The morning was fine and the day warm. We purchased from the Mandans a quantity of corn of a mixed color, which they dug up in ears from holes made near the front of their lodges, in which it is buried during the winter." A similar reference appears in a footnote on the same page: "Dispatched a perogue and 5 men under the Derection of Sergeant Pryor to the 2d Village for 100 bushels of Corn in ears which Mr. Jessomme let us have—did not get more than 90 bushels." The Reuben Gold Thwaites edition of the original journals of the Lewis and Clark expedition makes fifty-three references to corn in the index.

In 1806 Alexander Henry visited the Mandan. He wrote a fairly full account of their corn growing and says,** "We saw many children and women at work in the cornfield." He also states that he found the Mandan better and more extensive farmers than the Hidatsa.

John Jacob Astor thought he saw great opportunities in western fur trade, and in 1811 sent out the Hunt-Astor expedition to the Northwest. In the party was a man named John Bradbury, a botanist, who on his return published a book entitled "Travels in the Interior of North America." Since this man was a trained scientist, the following quotation, which is one of his many references to the Mandan corn, is of much interest:***

"The corn was now nearly a yard high. This is about the full height to which the maize (corn) grows in the Upper Missouri, and when this circumstance is connected with the quickness with which it grows and is matured, it is a wonderful instance of the power given to some plants to accommodate themselves to the climate.

"The latitude of this place is about forty-seven degrees geographically, but geologically many degrees colder, arising from its elevation, which must be admitted to be very considerable, when

* Coues, Elliott. History of the Lewis and Clark Expedition, p. 200. New York, Francis P. Harper, 1893.

** New Light on the Early History of the Greater Northwest; the Manuscript Journals of Alexander Henry and David Thompson, 1799-1814. P. 324. Edited by Elliott Coues. New York, Francis P. Harper, 1897.

*** Early Western Travels, vol. 5, p. 158. This enthusiastic explorer underestimated the time required for any known type of corn to mature.

we consider that it is at a distance of more than three thousand miles from the ocean by the course of a rapid river.

"This plant is certainly the same species of *zea* (corn) that is cultivated within the tropics, where it usually requires four months to ripen, and rises to the height of twelve feet. Here ten weeks is sufficient, with a much less degree of heat."

George Catlin,* a celebrated traveler and artist and an Indian enthusiast, lived with the Mandans in 1832. He has written much concerning their corn. The following is of special interest:

"The green corn is considered a great luxury. In this green state of the corn, it is boiled and dealt out in great profusion to the whole tribe who feast and surfeit upon it whilst it lasts; rendering thanks to the Great Spirit for the return of this joyful season, which they do by making sacrifices, by dancing, and singing songs of thanksgiving. This joyful occasion is one valued alike, and conducted in a similar manner by most of the tribes who raise the corn, however remote they may be from each other. It lasts but a week or ten days, being limited to the longest term that the corn remains in the tender palatable state; during which time all hunting, and all war excursions, and all other avocations, are positively dispensed with, and all join in the most excessive indulgence of gluttony that can possibly be conceived.

"The most remarkable feature of these joyous occasions is the green-corn dance, which is always given preparatory to the feast, and by most of the tribes in the following manner: When it is supposed that the ears of corn are nearly ready for use, several of the old women who are the owners of fields are sent by the medicine men to look at the corn every morning at sunrise, and bring several ears to the council-house, where a kettle is ready. These women do this every day until the medicine men decide that it is now in fit condition to use.

"They then send out criers who announce to all the villagers that the Great Spirit has been kind to them, and that they must all meet on tomorrow to return thanks for his goodness; that all must empty their stomachs and prepare for the feast that is to come.

"The next day when all are assembled a kettleful of corn is boiled. While it is boiling, four medicine men dance around the kettle. This first kettleful is given to the Great Spirit as a sacrifice. This over with the kettle is again filled and both medicine men and chiefs dance around it, all chanting songs of thanksgiving. When the medicine men decide that the corn is sufficiently boiled the dancing stops; the medicine men, chiefs and warriors are then

* Catlin, George. North American Indians, New York, 1841.

seated. Immediately the feast begins, the whole tribe now surfeit upon it and indulge in all their favorite amusements and excesses."

Maximilian, Prince of Wied, a German explorer and scientist, visited the tribes in 1833. He was a trained observer and is considered the best authority upon this tribe of Indians. He makes the following interesting reference in one of his diaries:*

"Of maize (corn) there are several varieties of colour, to which they give different names. The several varieties are:— 1. White maize. 2. Yellow maize. 3. Red maize. 4. Spotted maize. 5. Black maize. 6. Sweet maize. 7. Very hard yellow maize. 8. White or red-striped maize. 9. Very tender yellow maize.

. . . .

"The cultivation of the maize and other fields, of which each family prepares three, four, or five acres, takes place in the month of May. Rows of small furrows are made, into which the grains of maize are thrown singly, and covered with earth. Three times in the summer the plants are hoed, and the earth heaped up against them, that the moisture may have better access to them. The harvest takes place in October, when men, women, and children, each lend a helping hand. At present the women use, in their field labour, a broad iron hoe, with a crooked wooden handle, which they obtain from the merchants. Charbonneau (a French-Canadian interpreter who lived among the Indians many years) recollected the time when they used the shoulder blade of the buffalo for this purpose. The fields are never fenced, but lie quite open and exposed."

Will and Spinden** say, "The Mandans were, above all, an agricultural people, far more so than any of their neighbors. They have a tradition of having taught the Hidatsa how to cultivate the soil, and even the Arikara, who are said by some to have taught the Mandans, were somewhat inferior to the latter in the pursuit of agriculture." Will, who is probably the foremost student of the Mandans, has made the following summary of Mandan corn culture for this publication:

"Much has been said and written within the past few years about bringing the higher plains area of North Dakota and neighboring states into the corn belt, and but very few seem to know that this region has really been a corn country for at least two hundred years. When the first white man reached the Missouri

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* Early Western Travels, vol. 23, p. 275.

** Will, G. E., and Spinden, H. J. The Mandans: A Study of Their Culture, Archeology and Language. Papers of the Peabody Museum of Archeology and Ethnology, Harvard University, vol. 3, no. 4, p. 117.

River in North Dakota almost opposite this place in 1738 he was presented with native grown Indian corn by the Mandan Indians, and was much impressed with the great quantity of corn which he found that they had stored up. In this paper I hope to tell you something about this old corn culture, its extent, methods of cultivation, and importance to the people.

"It is probably a fact, though perhaps little thought has been given to the matter, that the plains Indians who lived in fixed villages as did the Mandans, Arikara, and Gros Ventres or Hidatsa, were in years past much more agricultural than they were found to be in historical times. The reason for this is evident when we stop to consider the magnitude of such a task as killing enough buffalo to supply a community of from one to several thousand people, living in the same vicinity year after year, with no means of pursuit other than the hunter's own legs. It is significant that Verendrye, who visited the Mandans on the Missouri River in the region of the mouth of the Heart River in 1738, speaks repeatedly of the great

FIG. 3. a, Typical hill of Mandan corn. The short stalk and abundance of leaves is a marked characteristic of these corns.

b, Typical hill of Chippewa corn. This corn came from the Red Lake, Minnesota, band of Chippewas, and is said to have yielded 90 bushels on the Red Lake Reservation in northwestern Minnesota.

abundance of agricultural foods and especially corn, and of the corresponding dearth of animal foods and fat. The coming of the horse as a swift means of locomotion wrought a great change in all the agricultural tribes and made the buffalo a much heavier contributor to their support than it had been. It should be remembered, therefore, that the agriculture which I shall try to describe is probably only a decadent remnant of what it was two hundred years ago.

"My information upon Mandan agriculture, aside from that drawn from old accounts, is derived chiefly from Scattered Corn Woman, an elderly Mandan matron, and daughter of the last Mandan Corn Priest. According to her the Mandans had at one time what they considered to be thirteen distinct varieties of corn. They were:

Soft yellow corn.
Soft white corn.
Red corn.
Spotted corn.
Blue corn.
Yellow flint corn.
White flint corn.
Clay red corn.
Pink corn.
Black corn.
Red, wrinkled corn, or sweet corn.
Society corn, described as having yellow kernels, streaked with red.
Keika corn. My interpreter did not have in her vocabulary the words necessary to describe this sort.

"Several of these varieties have now probably disappeared, among them the black and the blue, according to my informant.

"The varieties were always kept separate and planted in separate fields to prevent mixing. Each family kept and planted one, two or three sorts which were passed along from one generation to the next, and no other kinds were planted in the family fields.

"The fields were not large from our viewpoint, but when we think of the labor required in clearing and tending them with the rude implements used, the size seems more considerable. The Indian acre or nupka was not of a definite size. It consisted of seven rows of corn with a row of beans between each two corn rows; the length of the rows, however, was not fixed, and the land occupied by the squashes which were always a part of every garden and by the sunflower was not included in computing the acreage planted. As near as could be determined after much questioning an Indian nupka would on the average equal a piece of land between a third and a fourth of one of our acres in area.

"The fields were usually located both on the bottom lands and on the higher and drier first bench lands along the Missouri River. In the brushy bottoms the land was first cleared with a stone axe, a spot usually being selected where there were not more than one or two large trees, which were left standing. After cutting, the brush was burned in heaps on the ground, which was then raked over. After this the soil was dug up with a heavy, pointed ash stick some four feet long and one and one-half to two inches in diameter, called a digging stick, in hills about twelve inches in diameter and about a long step apart for corn. The beans were planted somewhat closer together but all rows were a long step apart. The field was frequently fenced with brush or a wicker work barrier to keep out the various animals, both wild and domesticated.

"When the fields had once been cleared the preparations for planting in ensuing years were not as arduous. The old stalks and vines, together with the dried weeds and brush still left on the field, were raked up with a rake of wood or of deer antlers, piled in heaps and burned. Then the old roots were removed and the hills were again dug up and the earth broken up with the digging stick and bone hoe. The first seed planted in the spring was the sunflower which was put in around the outside edge of the field when the Missouri River broke up, that is at the same time that the first field work started. Corn planting started about the first of May and was continued up to the first of June in the larger fields, every kernel being carefully placed by hand at the rate of seven or eight kernels to the hill. After the first of June the beans were put in, and lastly the squashes were planted at the time when the wild roses bloomed.

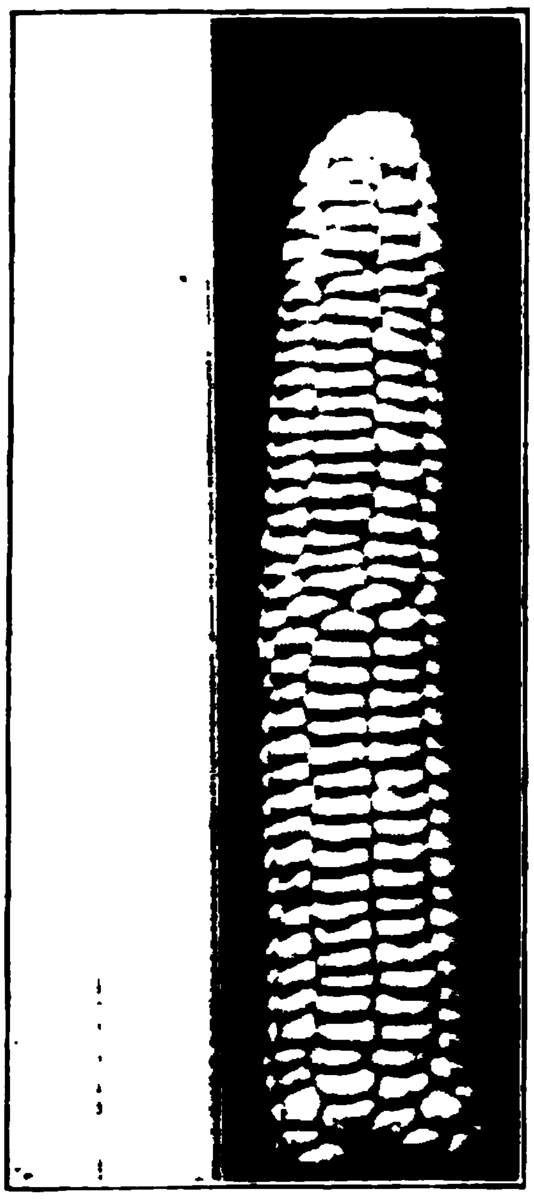

FIG. 4. Ear of Mandan soft yellow corn.*

"At the completion of the planting the hoeing began, and usually the field was entirely hoed through twice during the season. The hoeing was done with an implement having a handle about the length of a mattock or pick handle with a blade made from the shoulder-blade of a buffalo or occasionally an elk, or from

* Up to sixty years ago the Mandans kept their varieties free from mixture. They were by no means inferior as shown by the above typical ear.

a broad piece of buffalo horn taken from the base near the skull.

"The planting season and the double round of hoeing usually consumed all of the growing time. Most of the field work was done in the early morning hours, the women getting up with the sun and going out to the fields, often accompanied by the young girls, where they worked till the heat of the sun began to be oppressive, or their household duties called. A portion of the rest of the day was devoted to the regular household tasks and the remaining spare hours were spent in the much beloved fields. In the latter part of the season when the hoeing was nearly done, the afternoons were still spent in the fields, preferably with a daughter, or if there were no children, with the woman's husband, seated on the watching scaffold under the shade of one of the large trees usually left in the field, lounging, gossiping and singing, for the purpose of keeping the crows and blackbirds away.

"In families where there were several wives, each wife usually had her own separate field or fields. The size of the individual field ranged from one to four of our acres, often being increased a little each year up to the maximum workable size. When a family had planted from nine to twelve Indian acres, about three Indian acres of the corn were used green,—part in a prolonged feast of roasted green corn, and part boiled and dried for winter use. The remainder of the field was left to ripen. The average yield of the Mandan corn is placed by several of their early visitors at about twenty bushels per acre, exceeding this in especially good years.

"When the priest pronounced the corn ripe the whole village repaired to the fields. The corn was snapped from the stalk, husk and all, and thrown into piles in the fields, whence it was later carried in baskets to the drying scaffold in front of the family lodge in the village. In the work of the harvest only did the men take any part. At that time they labored in the fields with the women, the prospect of feasts especially prepared for them being the incentive.

"After the corn was all gathered at the scaffold all the good ears were braided into strings or traces by the husks. Such traces reached from the knee down around the foot and up to the knee again. These braids and cache-pits full were the two regular measurements of the amount of corn. The poor ears and nubbins were thrown loose on the scaffold floor to dry, then threshed out on an old robe or tent skin with sticks. As the corn was sorted for braiding the very best—ripe, large, straight-rowed, well filled ears were tucked into a sack by themselves. These were later all braided together and furnished the seed stock for the next season. All the braided corn was hung on the two-story stage or scaffold to dry and cure in the sun and air, the whole frame and sides being covered

with braids.

"When the corn was thoroughly dried it was taken down and stored in cache-pits in the ground. These pits were of a bottle-like shape, five to eight feet deep and four to six feet in diameter underground, having a capacity of from twenty to forty bushels. They were carefully lined with dried grass before putting in the corn and when full were covered with grass, a board fitted tightly in the neck or narow entrance hole, and dirt filled in and smoothed over to hide the opening. Every Mandan village was pitted with these caches, some of which were always inside the houses. They were opened during the winter when the need arose. One small pit was often reserved for the braids of seed corn in which there was a regular trade just before planting time in the spring. The other pits were first filled with braids over which the shelled corn was poured to fill in the interstices. Three pits of corn, somewhere in the neighborhood of one hundred bushels, was not at all an unusual amount for one family to store. When we consider that there were other caches of beans, dried squash and sunflower seed, it would appear that there was a considerable provision of agricultural food for the winter. In fact, so plentiful was the supply of stored corn that some was usually fed every day to the best war and buffalo horses. Maxmilian estimated that Fort Clark where he spent the winter near the Mandan villages had from five to eight hundred bushels of corn stored in its lofts, all of which the trader had purchased from the Indians. Lewis and Clarke speak of buying as much as ninety bushels of corn from the Mandans at one time beside very numerous smaller purchases; and Hayden says that often five thousand bushels were stored in the cache-pits in the fall.

"Among the Indians, as among all races that lack the art of writing, the place of history and literature is supplied by myths and stories passed on by word of mouth from one generation to the next, and the relative importance of various elements in the past life of the people is usually very accurately reflected in these accounts. In our present state of civilization, lodges and various societies with fixed rituals are very popular with a large proportion of individuals, and among the Indian tribes in most cases we find this banding together in lodges with long rituals of songs, dances, and spoken words a very prominent feature in the social organization. The fact that any specific thing is the center for a group of these ceremonies and ritual procedure proves the great material as well as religious importance of that article in the tribe.

"Of corn myths and stories and of ceremonials as well, the Mandans had many. Corn was very sacred to them; they must never let it be scattered about on the ground carelessly, and must always treat it with consideration and 'be good to it' as my Mandan

informant puts it. No knives might ever be used on either stalks or ears in gathering the corn. There was a corn priest in the village who had all matters pertaining to agriculture in his charge; also a women's agricultural society called the Goose Women, who supported the priest in his various ceremonials and duties during the planting and growing season. The priest fixed the time of planting and harvest; he ritually cleansed the seed to be sown, walked and prayed in the fields during the growing season, and performed certain ceremonies at harvest time. In some years under a special cleansing ceremonial observance he was practically the ruler of the village from seeding time till the harvest began.

"Corn personified appears in many of their myths and stories and the mythological first-giver of corn is held in very deep veneration. One of the most interesting stories, though a very long one, tells how the Corn Mother and Buffalo Brother were rescued from a great flood with the help of the Magpie. Another very long tale relates the life of Corn Silk Woman and her Son, who marries two wives, Corn Woman and Buffalo Woman. The Grandmother or the Old-Woman-Who-Never-Dies is the main figure in many stories and she is very closely identified with all things agricultural. She had huge fields of corn at her home on the Short Missouri and the birds, especially the geese and ducks who represent corn and beans, were her servants. When the geese flew north to her in the spring it was a sign to the Mandans to start clearing up their fields.

"In view of the many stories, traditions, and ceremonials dealing with the corn and of the importance of the corn priest in the tribe as well, it seems almost compulsory to believe that corn was, in the old days before the coming of the horse, the chief article of sustenance for the Mandan people. When we remember that in those days there were said by one of their early visitors to have been from thirty to fifty thousand individuals belonging to the tribe, we must conjure up a picture of the Missouri River Valley in North Dakota and especially in the vicinity of the mouth of Heart River as a broad region of waving corn fields such as has even yet not been duplicated by the white settlers, some of whom are still disposed to think that corn can not be successfully raised in western North Dakota and Montana."

HIDATSA

Rev. Gilbert L. Wilson,* who has been for some years a student

* Mr. Wilson began work among the Hidatsa in 1907, as an anthropological collector for the American Museum of Natural History of New York. Two years later he became a graduate student at the University of Minnesota and with the permission of Curator Wissler of the American Museum was given for thesis work the investigation of the agriculture of the Hidatsa and Mandan. In this work he received the kindly help and guidance of Dr. A. E. Jenks of the University of Minnesota.

of the Hidatsa tribe, has prepared for this publication the following summary of their cultural methods:

"The Hidatsas or Gros Ventres are a Siouan tribe, closely related to the Crows. Their traditions say that they came out of Devil's Lake, North Dakota; a war party wandering westward came to the Missouri, and observing an Indian village on the other side, crosed over; it was a village of Mandans, with whom they talked in the sign language. The Mandan chief gave the leader of the party half of an ear of yellow corn, the first the Hidatsas had ever seen. This ear was taken to the Hidatsa village, and furnished seed for fields which they now planted. Afterwards, the Hidatsas joined the Mandans and lived in adjoining villages, adopting the same culture. There are several variations of this tradition.

"The real facts are probably these: The Sioux originally lived on the Atlantic coast, in North and South Carolina. Sometime within the Christian era, they migrated west, descending the Ohio river, perhaps following the buffalo herds. At the mouth of the Ohio they broke up into groups, which became later the various Siouan tribes of the plains, Omahas, Osages, Missouris, Crows, Mandans, Dakotas, Assiniboine and others.

"All these bands, or tribes, brought a knowledge of corn culture with them, perhaps; but the numerous herds of buffaloes of the plains, tempted many of them to become hunters. The western or Teton Dakotas, and the Hidatsa-Crows were tribes of hunter Indians;

FIG. 5. Hidatsa maiden hoeing corn. Prior to the advent of the white man, each family of the upper Missouri River Indians raised from 2½ to 4 acres of corn. (Reprinted by permission of Rev. G. L. Wilson.)

while the Mandans, settling near the mouth of the Missouri, clung to their fields,—in fact the Dakotas, warring upon them, probably kept them from hunting as much as they would have liked. The pressure of the Dakotas also forced the Mandans farther and farther up the Missouri, on whose fertile banks they found a well watered soil.

"This slow pressing of the Mandans northward had an important result, as it slowly accommodated their varieties of corn to the harsh climate and short summers of the northern plains.

"The Hidatsa-Crows were originally one tribe, who joined the Mandans, perhaps as the tradition says. More likely the two tribes united for protection against the Dakotas. Later the Crows separated from the main tribe, and forsook their fields to follow the buffalo herds of what is now Montana. The Hidatsas adopted the Mandan culture, which they have in a measure preserved for us, after the near-extermination of the Mandans in 1837-8. The remnants of the two tribes, though speaking different dialects, dwell together practically as one tribe, on Fort Berthold Reservation, North Dakota.

"There seems little doubt that in the strains of the Hidatsa or Mandan varieties of corn, there are possibilities of great agricultural value to the two Dakotas and to Montana. The large number of well developed varieties, their apparent thorough acclimatization,

FIG. 6. Hidatsa lodge, showing seed corn drying on scaffold. The upper Missouri Indians were not wanderers. Each family lived in a separate earth lodge. The seed corn was picked early and dried upon a scaffold in front of the lodge. This tribe regarded seed corn as sacred and gave it great care. (Reprinted by permission of Rev. G. L. Wilson.)

the fact that variants are apparently still being produced, show that these native strains have two valuable qualities—they can stand a northern climate, and they are susceptible to further mutation.

"Aged Hidatsa women, who still cling to the older hoe culture, name five principal varieties of corn: ataki, or soft white; ataki tsoki, or hard white; tsidi tapa, very soft yellow; tsidi tsoki, hard yellow; and mailadishake, or gummy. Other varieties are, doohi, blue; hishi shepi, or dark red; hitsiisha, or light red; ataki-aku-hitsiisha, translated perhaps, pink-top; but these are apparently mere color variants.

"The hard white and hard yellow are flints, but with characteristics suggesting dent; the soft white and soft yellow are flour varieties; the maikadishake, or gummy, is a sweet corn. These five strains seem to be the ones most thoroughly fixed, and they are the ones the Indians recognize as typical. This is shown by the fact that each of the five varieties had its own way of cooking; the old Indians say that each variety could be distinguished by taste, even in the dark; but this was not true of the other color variants, which Buffalo Bird Woman, the writer's chief informant says, 'were for the most part like soft white; and we cooked them like that soft white, and they tasted like soft white.' There seem to be, however, one or two varieties of a flint that are red in color.

"Corn planting began in the first half of May, after sunflower seed had been planted. The field was raked free of debris and the stalks of last year's crop, and the dried piles of debris were burned. The corn was planted in hills, three or four feet apart, seven or eight kernels in a hill. The earth was loosened with a wooden digging stick, or with a hoe. Each corn hill stood exactly where a hill had stood the year before. Beans were commonly planted between the corn hills.

"Rakes were of wood, less often of the antlers of the black-tailed deer. Wooden rakes were lighter and easier to make, but had the objection that they were likely to impregnate the young corn with worms. Horn rakes were free from this objection.

"Hoes were of iron, with a heavy blade, but a relatively short handle. In older times, the blade was of the shoulder bone of a buffalo. There also seems evidence that hoes were made of the horn of a buffalo, with part of the flat skull attached; the writer has a specimen in his collection that seems to establish this conclusion, tho perhaps it might be well to seek further proof before asserting this positively.

"Scarecrows were made to frighten away the crows from the corn fields. They were not, the old folks sigh, very effective.

"As soon as weeds appeared after planting, the field was hoed. A second hoeing, and hilling up of the plants followed soon after.

"Rotation of crops and fertilization were not practiced, but when a field began to fail, it was let lie fallow for a couple of years. The value of the ashes left from burning over a newly made field was understood.

"Indians insist that corn culture by hoe is much harder now, owing to the abundance of weeds that have been brought in by white men. One curious custom was their carefully removing all dung of horses from the field in the spring, because 'weeds always came up where the dung lay and we thought that white man's cattle and horses brought the seeds.'

"Harvesting began about the last week in August. Husking was done in the field, the family getting up a kind of bee. Husking pegs were not used. Men and women worked together in the husking bee, and the young folks commonly looked upon it as a kind of lark, with opportunity for courtship.

"The fine large ears of the harvest, especially those that ripened first, were braided in strings of four or five dozen ears; and from these braids the seed corn was always selected. Smaller ears were borne to the village in baskets on the backs of women, and dried on the floor of the drying stage that stood before the door of every lodge. A booth of buffalo skins was made under the drying stage,

FIG. 7. Hidatsa corn tillage tools, made by Buffalo Bird Woman (age 76) of that tribe. When she was a young woman these tools were in use.

From top to bottom: Digging stick or plow, willow rake, bone hoe made from buffalo shoulder blade, deer's horn rake, braid of soft white Hidatsa seed corn. (Furnished the Montana Experiment Station through the courtesy of Rev. G. L. Wilson.)

and here the dried ears were beaten with sticks to thresh out the grain.

"Corn intended for seed was gathered early in the harvest and most carefully dried in the open air and the sun. As already said, seed corn was always braided.

"To store the grain for winter, cache pits had been dug, jug shaped, and about six feet deep, and lined with dry grass. The strings of braided corn, thoroughly dried, were laid around the walls of the cache, and the loose threshed-out grain was then poured in. In each cache was stored but one variety of corn. In the pit were often stored the coiled strings of dried squash. Buried in the loose grain, the squash slices were not spoiled by the damp.

"Hidatsa women were not wasteful ,and they had besides a deep veneration for the maize plant. Nubbins and imperfect ears went into the threshing pile if the grain on them was good. If a soft ear was found, it was laid aside for the horses. After the husking was over, ponies were let into the field to eat the standing fodder.

"Religious ceremonies were associated with corn culture; but as no extensive study of them has yet been made, at least of the Hidatsa ceremonies, our knowledge hardly permits a description.

"While tradition says that the first seed obtained was of yellow corn, the two white varieties seem, at least in later years, to be the favorites of the Hidatsa families.

"While the labor of caring for their fields fell mostly to the women, it must be said to the credit of the Hidatsas, that men commonly helped. Buffalo Bird Woman thus explains: 'Young men liked to paint their faces and be seen of the maidens; and we thought they should be ambitious and hunt buffaloes and go on war parties. But after a man got to be about forty years old he was no longer active and could not go on war parties. His place then was in the field helping his wife. He went ahead and made the hills while his wife followed and planted the corn. Also young men were taught not to use tobacco. But the old men planted tobacco fields. Women did not smoke tobacco, and never planted tobacco or cared for the tobacco plants. That was men's work.'

"One's estimation of the Indians is considerably raised by a study of Hidatsa agriculture."

HISTORY OF EARLY MONTANA CORN GROWING

There is no evidence to prove that the original Montana Indian tribes raised corn for food. While the Crows are a branch of the Hidatsa, who were corn raisers, they must have dropped their corn culture as a source of food when they migrated to the upper Yellowstone. Their traditions would not indicate that any considerable

thought was given to corn growing during their life in this State.*

However, there is evidence that this tribe raised it in a ceremonial way. Mr. Peter Koch of Bozeman acted as post trader at the "new Crow Agency" located on Rosebud Creek just above the confluence of Stillwater Creek in the spring of 1876. He states that that spring he witnessed a corn dance of that tribe and says, "I was greatly interested in the corn dance, and endeavored to secure some of their seed. However, I was not successful in even seeing the corn. They regarded the seed as sacred and kept the place where it was planted hidden. There is no question that only small quantities were planted and only enough for ceremonial purposes. They frequently had corn which they secured by trading with the Missouri River Indians. I was greatly interested in this corn as I wanted to see it growing that I might study it botanically."**

Will*** states that the Cheyennes, who now occupy a reservation on the headwaters of Tongue River and Rosebud Creek in the Yel-

FIG. 8. Hill of Indian corn from the Fort Peck Indian Reservation in northeastern Montana. This corn has been grown by the Indians on this reservation for twenty-five years and has always matured. It illustrates the relation of height of ears to growing season.

* Simms, S. C. Traditions of the Crows. Field Columbian Museum Publication 85, Chicago, 1903.

** This evidence by Mr. Koch is of much value. He came to Montana in 1869, is a university graduate, has decided historical leaning, and owns a fine collection of books relating to the history of the Northwest.

*** Will, George F. The Cheyenne Indians in North Dakota. In Proceedings of the Mississippi Valley Historical Association, vol. 7.

lowstone watershed, were at one time agricultural and raised corn. This was during the time they lived in North Dakota. Before 1780, however, they moved to the Black Hills country.

"The last remnants forsook the old village and the tribe was reunited near the Black Hills, no longer a sedentary agricultural people, but a nomadic host, flitting here and there, living in skin tepees, and subsisting on the fruits of the chase and such vegetable food as they might obtain in trading horses to their old neighbors, the Arikara and the Mandans. . . . . We are told that they still planted corn spasmodically for some time, yet the old life was gone and a new and absolutely different life had taken its place. With the abandonment of the Missouri River village the Cheyennes became in culture practically another race."

Mr. Duncan MacDonald, who is a member of the Flathead tribe and is undoubtedly the best authority on their social and economic life, in conversation with the authors said that originally the Flatheads did not raise corn but that between fifty and one hundred years ago the traders introduced it and corn has ever since been grown in their gardens. It was grown only in a small way but was regarded as one of their most delicious vegetables. They gained considerable knowledge of corn from Iroquois Indians who came with the traders as guides and helpers.

During the early part of the last century the Indian corn fields of the upper Missouri extended close to the present Montana line. That these fields were of economic importance is proved by the fact that in 1833 a fur-trading company erected the distillery previously referred to at Fort Union, which stood near the mouth of the Yellowstone.

It has long been known that there were corn-growing possibilities within this State. In 1862 Governor William Jayne,* in his first message, made the following reference to corn:**

"Thermal statistics and experiments prove that within the limits of our territory are to be found both the soil and climate

* Dr. William Jayne was a resident of Springfield, Illinois, and a neighbor and personal friend of Abraham Lincoln. He was appointed by President Lincoln as the first governor of the territory of Dakota. Dr. Jayne is still living in Springfield and very kindly granted the authors an interview concerning the early corn growing of that territory.

** Journal of the Council of the First Legislative Assembly of the Territory of Dakota, p. 10. Yankton, 1862.

necessary to produce most successfully the two leading articles of American agriculture,—corn and wheat. We find that starting from Chicago as a point, the isothermal lines rise to a higher and higher degree as we pass west. We find that Fort Benton, on the Missouri River, in the extreme northern part of Dakota possesses the same mean temperature as Chicago and Albany, New York.

"In the corn producing part of the country, which runs through Indiana, Illinois and extends north and west through Iowa, up the valley of the Missouri through Dakota, according to Blodgett, the author of a very valuable and interesting work on Climatology of the United States, the thermal capacity required for successful culture of Indian corn is a mean temperature of 69 degrees for July, and it may go a little beyond 65 for the summer. According to the same author, the thermal capacity required for the successful culture of wheat is a mean temperature of 62 to 65 degrees during the ripening months. Statistics prove that our territory possesses a considerable excess of the temperature required, being beyond 70."

In 1864 the supervising farmer stationed at the Fort Benton Indian Agency* stated that he had two acres of corn which, had it not been destroyed by floods, would have yielded more than 65 bushels an acre.

The first corn field of any size in Montana, of which we have an authentic record, was planted near Forsyth in the Yellowstone Valley in 1879. The information was furnished in a letter to the authors by Hon. T. E. Hammond,** as follows:

"The first corn planted in what is now Rosebud County was planted by Lou Getner in the spring of 1879. It is what we called squaw corn and was planted in sod—just plowed in.

"This corn had a very short growth, about 4½ feet in height, would yield about 35 bushels to the acre, and was considered the surest crop that could be grown at that time. In fact that was the only corn we grew until after the advent of the Northern Pacific in 1882, and from that time on different kinds of corn were brought in from different states.

"I saw some very fine yellow dent corn grown by Frank Coats in 1885 that would average about 40 bushels to the acre. All this corn was grown on non-irrigated land.

"At this time corn growing is no experiemnt in Rosebud County

* Report of Commissioner of Indian Affairs. Washington, 1864.

** Hon. T. E. Hammond of Forsyth, is one of the oldest ranchers and farmers in the Yellowstone Valley and has always been active in his efforts to improve Montana's agriculture.

as I have seen some fields of corn grown in Pease Bottom as good as I ever saw in my native state (Illinois). This corn was irrigated and properly cultivated and would yield about 70 bushels to the acre."

Since ranching was the principal agricultural pursuit in the State at this time, very little corn was grown. In 1888 Dakota White flint was introduced and since that time has been widely grown, especially in the Yellowstone Valley. Mr. R. N. Sutherlin, who was one of the state commissioners in charge of Montana exhibits at the World's Fair in 1893, says that an early variety of white flint corn (probably Dakota White) that was grown in Dawson County won several prizes in its various classes.

The stock rancher was not a farmer, and aside from a small patch for chicken feed very little corn was grown until the advent of the dry-land farmer. In the last few years corn has been quite extensively planted over the plains region of the State.

In 1910 Mr. J. J. Hill gave $1000 for prizes in county school children's corn contests. The demonstration by the school children that corn could be raised has done great good. For a number of years the county commissioners of Yellowstone County have annually appropriated a certain amount of money to be used as prizes in county school contests in corn growing. These contests have been carried on under the direction of the county superintendent of schools and of Mr. I. D. O'Donnell of Billings. There has been a constant improvement in the corn and now the exhibits would be a credit to any corn-producing community.

In 1914 the first exclusive Corn Exposition of the State was held at Miles City, at which time over four hundred exhibits of corn were entered. At the present time the corn acreage is increasing very rapidly.

Part III. Classification and Variety History

As the corn belt of the United States has expanded, varieties of corn have constantly been created to meet the new climatic conditions. These varieties have been developed in two ways: (1) By adaptation and selection from strains of corn introduced from older sections; (2) by crosses made with introduced varieties on native corn.

The classification of corn depends very largely on the angle from which it is viewed, and the groups are differentiated in this bulletin chiefly by economic characteristics, such as type of kernel, length of growing season, etc.

Conditions in the state of Montana vary greatly; therefore there are demands for different types of corn. Our corn-raising sections are unlike Iowa and Illinois, in that there is a variation in altitude of about 2,000 feet, and variations in the moisture supply from a precipitation of thirteen inches on dry-land farms to all the irrigation water that can possibly be utilized. It is quite evident, therefore, that types of corn must vary greatly throughout the State.

The classification of corn into groups or types is a very difficult matter. Corn is open-pollinated, and the pollen is so light that it can be carried by the winds considerable distances. This characteristic of the corn plant, coupled with the fact that farmers everywhere are developing new strains, accounts for the almost innumerable varieties of corn. It is very difficult to select a basis of classification that will include the essentials of botanical structure and agronomic value. Sturtevant* in 1899 published a classification of North American varieties of corn and their synonyms. His classification is based on the kernel,—structure, color, size, etc. While his paper is of great value, unfortunately but little attention is given to the stalks or to the varietal history. This paper was written prior to the activity of the experiment stations in the Middle West in corn breeding and the standardization of corn by the experiment stations and the corn growers' associations.

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* Sturtevant, E. L. Varieties of Corn. U. S. Dept. Agr., Office of Experiment Stations, Bul. 57.

The authors have examined Dr. Sturtevant's material and his unpublished notes which are in the library of the Missouri Botanical Gardens.

The following classification is not considered ideal, for in many cases it is hard to mark definitely the line between the early and late groups. Earliness is a quality that cannot be expressed in exact terms. The authors believe, however, that this is the simplest and yet the most comprehensive classification that can be given at this time.

I. Early flint group.
II. Late flint group.
III. Semident group.
IV. Early dent group.
V. Late dent group.

EARLY FLINT GROUP

There are two distinct types of flint corn, early and late, having much the same type of ear and kernel but differing widely in their maturity and stalk growth. The early flints are the earliest type of corn, so far as the investigations of this experiment station go, and are also the highest yielders so far tested on dry land. The stalks range in height from three to four feet, the internodes are short and compact, and the main ear is usually produced on the third node. They are very prolific and often produce two well developed ears on one stalk.

The table of leaf surface data (Table III) shows that the shortness of stalk does not reduce the leaf surface proportionately. This type of corn produces normally two basal tillers and one or two ear shoots. The ears are six to ten inches long and eight to ten-rowed. This group will stand more hardship in the way of drought,

FIG. 9. Parts of a flint kernel.

hot winds, and poor cultivation than any other sort. It will mature corn ripe for hogging off in from seventy to ninety days, depending on the local conditions. The ears are produced from four to fourteen inches above the ground; consequently it cannot be harvested with the corn binder but is most profitably harvested in the field by fattening stock. This group has been directly derived from corn grown by the northwestern Indians.

Careful studies on the amount of water required to produce one pound of dry matter have not been conducted at this station. However, the Office of Dry-Land Agriculture of the U. S. Department of Agriculture* reports the following results which were secured at its station at Akron, Colorado. The Indian flint corn required 342 pounds of water to produce one pound of dry matter, while the Northwestern Dent required 377 pounds, and the Iowa Silvermine 407 pounds. Observations in this State indicate that the early flint corns will produce more feed under limited moisture conditions than any other group. Their ability to withstand heat should also be noted. Their low, bushy habit of growth renders them less susceptible to hail damage than later, coarse-growing varieties.

This group was first described by Nuttall, an English botanist who visited the Mandan early in the last century. His description has been referred to by the early agricultural writers more as a curiosity than as having economic value. Flint** says, "Nuttall describes a variety called the early Mandan corn, cultivated by the Aborigines about the Missouri."

Brendel*** states, "One variety, the early Mandan corn (Zea Mays, b., Praccox, with a very short culm, spathes arising from the base of the culm, seeds mostly in eight rows, Nutt., Gen. II., 203) is successfully cultivated by the natives on the upper Missouri, as high up as its sources, ripening in a climate where no other variety could exist."

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* Briggs and Shantz. Moisture Requirements of Corn. U. S. Dept. Agr., Bur. Plant Indus. Bul. 285.

** Flint, Charles Louis. An Essay on the History and Importance of Indian Corn. In Transactions N. Y. State Agr. Soc., vol. 9, p. 291. Albany, 1850.

*** Brendel, Frederick. Historical Researches upon the Cultivated Grain Fruits of Illinois. In Transactions Ill. State Agr. Soc., vol. 2, p. 475. Springfield, 1856-7.

Cobbett,* an Englishman who visited America early in the last century and whose writings L. H. Bailey says are "more interesting than scientific," describes this type of corn and gives several drawings of the stalk, ear, etc.

The varieties in this group that are recommended are Dakota White Flint, Gehu Flint, Burleigh County Mixed, Early Indian, Fort Peck, and Early Starch.

LATE FLINT GROUP

This group consists principally of flint corns originating in New England and in the South. The stalks range from five to seven feet in height and are finer in quality with shorter internodes than dent stalks of the same height. They have a marked tendency to produce numerous suckers or tillers and consequently have a high leaf area as shown in Table III. The ears are usually long and slender with

FIG. 10. Field of Longfellow late flint. Fine stalks and an abundance of leaves are characteristic of this type of corn.

white cob and either white, yellow, or red kernels. They vary greatly in the length of time required for maturity and as a general rule will mature only in the lower, hotter sections of the State. All of the varieties can be easily cut with a corn binder. They are recommended either for fodder or silage. It will be noted in Table VI

* Cobbett, William. A Treatise on Cobbett's Corn. London, 1828.

that they have a high proportion of leaves and fine stalks. In New England and other northern states they are commonly used for ensilage. The varieties tested and recommended as promising in Montana are Triumph, Longfellow, Mercer, King Philip, and Smut Nose.

SEMIDENT GROUP

This group of corn is designated "semident" because of broad, rounding kernels that are neither true dent nor true flint. The kernels contain more horny gluten than true dent kernels and more starch than typical flint kernels. The stalks closely resemble the early dent group but have a greater proportion of tillers. The stalks are about 5 feet 3 inches tall and produce ears about 20 inches from the ground. The nodes and leaf surface correspond more closely to the dent than to the flint group. In maturity they rank very close to the early dents and are about two weeks later than the early flints. As the ears are quite short, threshing is the most economical method of securing the grain. The most common varieties are Northwestern Dent, Minnesota 23, and Minnesota King.

FIG. 11. Parts of a semident kernel.

EARLY DENT GROUP

These corns are extremely early adaptations of the common

dent corn. The stalks grow from 4 to 5 feet high and the ears are borne 18 inches from the ground The nodes are not particularly shortened and consequently the leaf surface is not as great as in those types that produce shorter internodes. They bear but few suckers and the stalks are not coarse as compared with the late dents. The kernel is typically dent, though it occasionally tends towards the shallow, rounding, semident type. The ears are short, the greater percentage being under 6 inches rather than over. These corns are about seven to ten days later in maturing than the early flints. They mature in from eighty-five to one hundred days, depending on the heat units and the altitude. These corns produce a combination of fine stalks and small ears and consequently are most economically harvested with the corn binder, then threshed or shredded when properly cured. The varieties tested and recommended are Rustler's White Dent, Square Deal, Disco Early Pride, Pioneer White Dent, and Eiker's Yellow Dent.

LATE DENT GROUP

The term "late dent" in this State is used to designate dent corns that will mature only in the lower, hotter valleys or in excep-

FIG. 12. Parts of a dent kernel.

tionally favorable years. The line of demarkation between the early and the late dent groups is not clearly shown. The latter produce stalks from 6 to 8 feet high. These are coarse with a large percentage of pith. The ears resemble the dent corns of the Middle West in size and character. These corns require from 110 to 130 days, with a high number of heat units, for maturity. They are utilized in Montana to a certain extent for grain and forage, but their largest use is for ensilage. The varieties most commonly known are Minnesota 13, Wisconsin No. 8 or Silver King, Murdock's Yellow Dent, Sterling White Dent, Payne's White Dent, and Pride of the North.

HISTORY, DISTRIBUTION AND CHARACTERISTICS OF VARIETIES

The period of the development of the corn belt commenced early in the last century when civilization poured over the Alleghanies and began settlement of the rich Ohio valleys, and it closed between 1870 and 1880 when the free lands of eastern Dakota, Nebraska and Kansas were exhausted. During this period "corn was corn." Low prices as a natural result of cheap and free land did not stimulate the general improvement of the great crop. However, development of the leading varieties by selection had begun but had not progressed far enough to receive much mention in the agricultural literature of the period.* The first five volumes of the Transactions of the Illinois State Agricultural Society, 1853 to 1864 inclusive, do not even mention varieties of corn, let alone giving a list of recommended varieties adapted to certain districts. Beginning, however, with the establishment of the U. S. Agricultural Experiment Stations in 1885, more and more attention was given to corn improvement.

About the beginning of this century land values in the corn belt began to rise and almost coincident with this Prof. P. G. Holden of the Iowa Experiment Station published a well illustrated bulletin dealing with corn improvement and corn judging.** This was immediately patterned after more or less by all experiment stations within the corn belt and was the beginning of a psychological evangelism for better corn which was far reaching in its effects. During this

* Lloyd, W. A. J. S. Leaming and His Corn. Ohio Experiment Station, 1911. This publication describes the origin and development of the Leaming corn, which was one of the earliest recognized varieties in the corn belt.

** Iowa Experiment Station, Bul. 68.

time, however, varieties were moving west and adjusting themselves to slight changes in climate; consequently varietal history and a previous movement were of little importance.

FIG. 13. a, Dakota White Flint (early flint); b, Gehu (yellow early flint); c, Burleigh County Mixed (mixed early flint).

However, the case is entirely different in Montana. All the corns grown here have been imported from states to the east and south. Since this State requires corns of certain specific types and characteristics which are the result of breeding and selection, it is of very great importance that we know under what conditions these imported varieties have been growing in the past and the manner in which they were improved. Hence the detailed historical material which follows.

DAKOTA WHITE FLINT (EARLY FLINT)

Synonyms: Will's Dakota, North Dakota White Flint.

History.—This corn was originated by Mr. Oscar H. Will of Bismarck, North Dakota, who furnished the authors with the following information regarding it:

"In the spring of 1882, Major Fuller secured a small quantity of squaw corn from a friend at Fort Stevenson. Owing to the extremely dry season of 1881 the ears were only about the size of a good sized finger and composed of many colors. I planted this corn the 24th day of June on some vacant lots on Fourth Street above Avenue B in this city. The plot was newly broken and I used a hatchet to plant the corn, by chopping a gash in the sod, twisting the hatchet slightly to make a slot to drop the kernels through and closing it with my foot. Nothing further was required except to harvest, which was done very early in September. The stalk of this corn was very short and the ears came from the first joint at or near the surface, in fact, some of them seemed to come right out of the ground.

"I made my first selection of the white kernels from this crop which was the beginning of the present Will's Dakota. It was ten years before I got the color perfect. I have always selected for a small cob which shells more corn than the large cob."

This corn was first catalogued by Mr. Will in 1886 under the name of "Pride of Dakota," with the following description: "A white flint corn brought to its present stage of perfection by carefully selecting for four years the finest ears which were the first to ripen. and from such ears selecting the most perfect shaped kernels from the improved white squaw corn. I claim that this corn is the earliest in cultivation. It matures in seventy days."

Thus the Dakota White is the old Mandan corn. As was noted in the discussion of the Mandan corns, they had a variety which they

termed the Hard White. After the advent of the white civilization the Indians neglected their corn culture to a certain extent and allowed the varieties to mix. Mr. Will's selection was probably an isolation of the pure strain of their hard white corn and an improvement of it. This corn has been widely disseminated and is perhaps the earliest flint corn in the Northwest. It will stand more hardship in the way of heat, frost, and poor cultivation than any other variety.

Distribution.—This corn is widely distributed over northern and western North Dakota, southern Manitoba, and the entire corn-raising section of Montana.

Characteristics.—Early flint; ears 6 to 10 inches long and gently tapering; eight to twelve rows of kernels; kernels white, small, and blocky; cob white; stalks from 28 to 48 inches high, according to season; ears borne from 4 to 10 inches from the ground; numerous suckers and fine leaves.

FIG. 14. From left to right: Burleigh County Mixed (mixed early flint); Gehu (yellow early flint); Dakota White Flint (early flint).

GEHU (YELLOW EARLY FLINT)

Synonyms: Seventy-Day, North Dakota Early Yellow Flint.

History.—Mr. L. D. Judkins, of Bismarck, North Dakota, crossed the Dakota White Flint with the Mercer Yellow Flint about 1887 or 1888. In 1889 Mr. Will bought all the seed from this cross and all rights to its introduction and sale. He catalogued it the same year for the first time, offering it only in very small quantities. It was not catalogued again until 1892, the intervening three years being used to get a purer variety by selection. It was listed in his 1892 catalogue as follows: "This is a new hybrid flint corn of beautiful, bright, glossy yellow color. I claim it to be the earliest valuable field corn in the world and superior to all other varieties of flint corn for cultivation in the Northwest." It was awarded first prize at the North Dakota State Fair in 1894. This corn derives its name, Gehu,* from the biblical man who "got there quick."

Distribution.—This corn is now quite widely grown over North and South Dakota and Montana. It has been exported to various countries on the globe and is mentioned as one of the most promising corns of South Africa.**

Characteristics.—Early flint; ears 8 to 10 inches long, gently tapering; ten to twelve rows of kernels; lemon yellow color; cob white; stalks from 36 to 48 inches; ears borne 8 to 10 inches from the ground; numerous suckers and fine leaves.

BURLEIGH COUNTY MIXED (MIXED EARLY FLINT)

Synonym: Early Improved Mixed Flint.

History.—This corn is the improved mixed corn from the Mandan Indian origin. At the time of the first settlement of Burleigh County, North Dakota, the farmers secured seed corn from the Indians, which some of them have been raising ever since. This corn was catalogued by Mr. Will in 1887. It is of many colors and is simply a selected mixed Indian corn of quite high yield and good quality.

* II Kings 9:20. "And the driving is like the driving of Jehu, the son of Nimshi, for he driveth furiously."

** Burtt-Davy, Joseph. Maize: Its History, Cultivation, Handling and Uses, pp. 315, 317. London and New York, Longmans, Green & Co., 1914.

Distribution.—Western North Dakota and eastern Montana.

Characteristics.—Early flint; ears 8 to 10 inches long, gently tapering with butt frequently expanded; eight to twelve rows of kernels; color mixed—yellow, white and red; cob white; stalks 36 to 50 inches; ears borne 8 to 12 inches from ground; numerous suckers and fine leaves.

MIXED INDIAN CORN (SQUAW* CORN, EARLY FLINT OR STARCH)

This name is usually applied to the present-day mixture of types and varieties of Indian corn. Historical evidence indicates that, prior to association with the whites, the Indians grew more or less distinct types of corn. However, with the introduction of the white man's ways and the resultant loss of their tribal life and traditions, came a degeneration in their corn culture. The separate strains were Hard White (Flint), Soft White (Starch), Red, Blue, Yellow, and Mixed. The stalks of the mixed Indian corn are typical of the early flint groups and the ears usually contain great kernel mixture. Since they are of hybrid origin and have had no continued selection, they exhibit great variation.

Distribution.—Entire northwestern corn-producing region.

Characteristics.—Early flint; varies greatly according to origin of corn; very similar to Fort Peck Indian corn.

FORT PECK INDIAN CORN (MIXED EARLY FLINT)

This is a mixed Indian corn of Mandan origin. It has been grown by the Indians on the Fort Peck and Fort Belknap reservations in northern Montana since their organization, over thirty years ago. The corn has been grown principally in a crude way on the Missouri bottoms and used for roasting ears or parching. The Indians, being fed by the Government, have not had to depend on their corn as a source of food and consequently it has received little attention. Dr. J. L. Atkinson, the Agency physician, took note of its earliness and has grown and improved it on his ranch south of Poplar, Montana. In 1912 he had a number of early corns

* The writers do not sanction the use of the name Squaw. At present the word carries with it a reflection intimating an Indian woman of inferior character. Surely American corn growers will not approve of any disrespect to the good Indian mothers of long ago who adapted corn to our climate.

planted on the ranch. The season was abnormally cool and the killing frost came exceptionally early, with the result that the Native Squaw, as it was called, was the only variety that matured. This experience was reported to the agronomy department of this station by Dr. Atkinson, who sent a quantity of seed for experimental purposes. It has been the earliest maturing corn so far tested and has ripened from 25 to 40 bushels of corn at the Bozeman and the Moccasin stations.

The corn is greatly mixed and frequently contains on the same ear both starch and flint kernels of yellow, white, red, and blue colors. The stalk is very short and the ears are produced very close to the ground.

Characteristics.—Early flint; ears 4 to 8 inches long, slightly tapering; eight rows of kernels; color mixed—red, yellow, white, and blue; mixture of flint and flour kernels, frequently on same ear, cob white; stalks 24 to 30 inches; ears 4 to 6 inches from ground; many suckers and ear leaves.

STARCH OR FLOUR CORN

This is the general term that applies to the soft-kernel type of Indian corn. Horny gluten is almost absent in this corn. In the discussion on Indian corn growing in this bulletin, mention was made that each of the varieties or types was cooked or prepared for food in a way peculiar to itself. No doubt in the old days starch corn was greatly prized because of the ease with which it could be pounded into meal. Practically all corn-growing tribes had starch corn. Therefore there are many sub-types which differ in color and period of growth. The northwestern Indians had starch corns of white, yellow, and shades of red. The corn is now mixed and commonly called squaw corn. In point of yield and chemical feeding value, they average about the same as the early flints. Since they are easily masticated they have been widely recommended for hogging-off purposes.

But little attention has been given to these corns in the Northwest. So far only one variety has been catalogued by seed firms in North Dakota. The Amenia-Sharon Land Company, of Cassel, North Dakota, has catalogued a large, soft, flour corn. Mr. Walter Reed, manager of the company, describes it as follows:

"We have been experimenting with a very peculiar variety resembling white flint in appearance but with a different consistency. This grows rather low on the stalk so that it cannot be cut with a corn binder to advantage and in that respect resembles squaw corn. The ear, however, is very much larger than the regular squaw corn, and the kernel is of a different nature, it being a soft, floury kernel instead of being hard and flinty. We got a few ears of this corn three or four years ago from South Dakota. I think it is grown there only by one man and I do not know where the original stock came from. The first year it was inclined to mature later than our Northwestern Dent but since that time it has improved and now matures as early as the other corn and safely before frost. My idea as to this corn was that it would be valuable for 'hogging off' but everyone I showed it to seemed to be skeptical as to its feeding value. In order to satisfy myself on this point I submitted some of the corn to Professor Ladd of the Agricultural College for analysis and I am enclosing a copy of his letter, from which it appears that it is of good quality for feeding. * * * For want of a better name, we call this corn Ivory King."

Characteristics.—Early flint; ears 8 to 12 inches long, slightly tapering, with tendency toward cylindrical; eight to fourteen rows of kernels; color usually white with occasional shades of pink; stalks 36 to 60 inches; ears 8 to 20 inches from ground; leafy with numerous suckers.

OTHER EARLY FLINT VARIETIES

Among the varieties tested were a number that belong to this class. The Early Canada is a low-growing variety somewhat similar to Dakota White, which has been grown in northern New England and southern Canada since colonial times.

The Beal and the Bolley are local varieties grown in Morton County, North Dakota, and are descendants of the Indian corn. They have not been selected so carefully as the Dakota White or Gehu, and it is doubtful if they possess qualities which would place them alongside these standard early flints.

The Rea corn is a South Dakota selection of Indian corn which has been grown by the tribe of Indians from which it gets its name. These lived along the Missouri River and its tributaries in South Dakota. It is a starch or flour corn and undoubtedly a progenitor of Ivory King. Its stalk and ear characteristics are similar to Dakota White Flint, except that it is somewhat larger.

MERCER (YELLOW LATE FLINT)

Synonym: Rideout.

History.—The corn was first catalogued as the Rideout or Mercer corn by the Northrup, Braslan, Goodwin Company, of Minneapolis, in 1888. Northrup, King & Company are uncertain as to its origin but are of the opinion that it was a New England corn originally but grown in Wisconsin prior to their securing it. Sturtevant describes this corn and gives several synonyms, among which are Dutton corn, Connecticut State Experiment Station, 1893, Improved Dutton, Twelve-Rowed Flint, and Connecticut Experiment Station. It was also classified as Early Dutton and described as such by Henderson in 1884, and as Early Summer Flint by Landreth & Sons, Philadelphia. It was described as having an ear from 9 to 10¾ inches long with rather small, shallow, golden-yellow kernels in twelve rows. The ear was usually slightly enlarged or expanded at the butt. Sturtevant describes specimens from Massachusetts, Connecticut, Minnesota, Michigan, and New York. This would seem to indicate that the Mercer corn was a fairly well distributed New England corn, known by the general eastern name of Dutton. Mercer was probably a western name.

Northrup, King & Company gave the following description of this variety in their seed catalogue for 1888:

"A yellow flint variety that has been grown in this state for the last four years with complete success and satisfaction. It is decidedly the largest eared and handsomest flint corn grown in the Northwest. Very prolific, having yielded 164 bushels of good sound ears and 7 bushels of nubbins per acre. Ears range from 9 to 11 inches in length; 12 to 14 rows; well filled out at the tips. Has a rich golden color. Has matured in 75 days from time of planting. Many stalks have two and sometimes three good ears each."

Salisbury,* who wrote the first American agronomic paper on corn, gives a classification and description of the Dutton corn as follows:

"1. Those the Kernels of Which have a Corneous Portion and are neither Shriveled or Indented.

"A. Those with yellow kernels and a white cob.

"(a.) The Golden Sioux, or Large Yellow Flint.

* Salisbury, J. H. History and Chemical Investigations of Maize or Indian Corn. In Transactions of N. Y. State Agr. Soc. Albany, 1848.

"A large 12-rowed variety, obtained originally from the Sioux Indians. It is one of the largest kinds of this group, and is considered a superior variety. It is much cultivated in the middle and western part of this State. Ears generally from 8 to 12 inches long. Diameter from 1½ to 2 inches. Corneous portion of kernel greatly predominates. Seed thickly set upon a firm cob, which is generally well filled out at its summit with bright kernels. Width and depth of kernels sub-equal. . . . Ripened in 16½ weeks after planting. . . . Ears yielded 78.26 per cent of kernels and 21.74 per cent of cobs. There are several sub-varieties of the Sioux, among which is the celebrated Dutton corn,—a variety first brought into notice in 1818 by Mr. Salmon Dutton, of Cavendish, Vermont."

In Salisbury's experiments this variety, which was planted on May 12th, was matured by September 6th and yielded at the rate of 69 bushels of shelled corn and 6,622 pounds of air-dry fodder. The stalks grew 6 to 8 feet high and averaged two suckers per plant, and the ears were often fourteen, sixteen, or eighteen-rowed.

While D. J. Brown was superintendent of the Agricultural Division of the United States Patent Office (in the early 50's), he was especially interested in corn and the reports of the Division from 1849 to 1862 contain considerable valuable material on the varieties and culture of that period. Dutton corn is frequently mentioned in the reports. The following* from Oswego County, New York, is a typical illustration: "The Dutton is in favor with many, as it yields well, produces a large amount of fodder, and is easy to husk from, the ears being large. It is, however, a week later than the eight-rowed yellow, which is in most common use." In the report of the Patent Office for 1853 a correspondent in Niagara County, New York, mentions the Dutton as a twelve-rowed yellow corn.

Brown,** in listing varieties, speaks as follows:

"Golden Sioux, or Northern Yellow Flint corn, derived from the Sioux Indians in Canada, having a rather large cob, rather short as to length, with twelve rows of moderately sized grain, abounding in oil, is regarded as one of the best varieties for fattening animals or for human food. With skilful handling 130 bushels have been

* Report of Commissioner of Patents for the Year 1849, Part II, Agriculture, p. 226. Washington, 1850.

** Brown, D. J. A Memoir on Indian Corn. New York, C. M. Saxton & Co., 1856.

raised to the acre, weighing 9,216 pounds in the ear. When dry 75 pounds made a bushel when shelled. Several hybrid varieties have been produced between the Sioux and the King Philip."

Later, Brown gives this description of the Dutton corn:

"The Dutton corn, a variety first brought into notice by Mr. Salmon Dutton of Cavendish, Vt. The ears of corn from which it was selected were on the average 8 to 12 inches long and contained twelve to eighteen rows. The cob is large and sometimes grows to a length of 14 to 15 inches, but the grain is so compact upon it that two bushels of shelled ears have yielded five pecks of shelled corn weighing 62 pounds to the bushel. With proper management an acre of ground will produce from 100 to 120 bushels. As it abounds in oil, gives a good yield, and ripens at least two weeks earlier than the Canada corn, it has long been a favorite for culture in the north."

Enfield* says of the Dutton corn: "The stalk is of medium height, and the cob comparatively large, with ten to twelve rows of grain. The grains grow very compactly on the cob, and the ears being well filled out at the tips, and of a rich glossy color, present a very fine appearance."

Arthur C. Parker, of the New York State Museum, in a letter to the authors, says: "I am inclined to believe that Dr. Brown may have been in error in attributing it to the Sioux Indians of Canada, unless he referred to the overlapping linguistic stocks of that family. It is quite likely that the corn in question was a hard flint type grown by the Iroquois or Algonquin tribes along the Great Lakes and St. Lawrence."

This Dutton corn seems to have attracted wide attention in New England. Deane** says that the Massachusetts Agricultural Repository contains a statement of the production of one acre of land cultivated by Jonathan Hunnewell, Esq., in 1819. This acre produced 78¼ bushels of corn when shelled. The seed came from Vermont and "is the same sort, we believe, which has been advertised in the newspapers as the Dutton-corn." In 1820 the same plot of ground was again planted to corn and this time yielded 111 bushels, for which the grower received a premium from the Massa-

* Enfield, Edward. Indian Corn: Its Value, Culture and Uses, p. 62. New York, D. Appleton & Co., 1866.

** Deane, Samuel. The New England Farmer; or Georgical Dictionary, p. 226. Boston, Wells and Lilly, 1822.

FIG. 15. a, Robertson (yellow early dent); b, Mercer (yellow late flint); c, King Philip (red late flint); d, Longfellow (yellow late flint).

chusetts Agricultural Society. This corn was ripe the 13th of October and it is stated that "in good seasons it requires but ninety days to ripen."

Fortunately we have been able to trace the history of the Mercer corn more definitely than that of any other variety. The evidence seems to show that it has always been a heavy yielding flint corn, of twelve or more rows.

Distribution.—New England, southern Canada, and the whole of the northern, middle, and western states.

Characteristics.—Late flint; ears 8 to 12 inches long, slightly tapering, tending towards cylindrical; eight to twelve rows; kernels orange yellow; cob white; stalks 5½ feet to 6 feet; ears 18 inches from ground; numerous suckers.

TRIUMPH (YELLOW LATE FLINT)

History.—This corn was introduced by Northrup, King & Company in 1899. They state that it is the largest eared and most productive of all the flint corns. It was produced by straight selection from the Mercer corn for a larger ear and greater number of rows, with larger stalk and greater leaf surface. Stalks are fairly tall and extremely leafy, which makes it a very desirable corn for fodder or silage purposes.

Distribution.—North Dakota and eastern Montana.

Characteristics.—Late flint; ears 8 to 12 inches long, approaching cylindrical; twelve, and occasionally fourteen and sixteen, rows of kernels; color orange yellow; cob white and large; stalks 5 to 6 feet; ears 20 inches from ground; numerous suckers and fine leaves.

LONGFELLOW (YELLOW LATE FLINT)

History.—Salisbury classifies three types of New England eight-rowed yellow flint.

"Large 8-rowed Yellow Flint: Ears long and very slender; rows generally arranged in twos at base of ear. Kernels large, and thickly set upon a firm cob, which is often covered at apex with small rusty kernels. Length of ears from 8 to 12 inches; diameter, from 1 to 1½ inches. Tapers but slightly till near its summit. Kernels wider than deep. Ears yield 79.74 per cent of grain and 20.26 per cent of cobs. Planted May 12th and ripe September 15th. Height of stalk, 7 feet 10 inches. Average number of suckers, two."

This variety is extensively cultivated and considered by many the best of the yellow flints. He further states that there is a middle-sized, eight-rowed yellow flint, with ears from 6 to 10 inches long and usually more cylindrical and generally thicker set than those belonging to the preceding variety. This, like the former, is extensively cultivated in this State and may be ranked among the best varieties of the yellow corn.

There is also an "early 8-rowed Canada, or Canadian Yellow Flint: Ears small, 8-rowed; kernels small and thickly set upon a dense cob. This is an earlier and much smaller variety than either of the preceding."

Sturtevant* asserts that the Longfellow is a variant of the New England Eight-rowed, which is rather a coarse type, in general cultivation in New England, and presents two forms,—one northern or short ear, and the other southern or long ear. He also mentions numerous strains which may be classed as synonyms. His classification places them under two forms; one the New England Eight-rowed Improved, which he states is "a readily recognized variant of the New England Eight-rowed, offering a number of strains which can only be classed as synonyms." He describes the ear as 9 to 12 inches long, 1½ inches in diameter, usually a little enlarged at the butt; eight-rowed; kernels broad, rounded, and golden yellow; cob white. He mentions receiving specimens from Gregory in 1884. He also classifies it under the Waushàkum, which he states is a variant form of New England Eight-rowed early corn, grown under various names which must be considered synonyms. He gives practically the same description as for the New England Eight-rowed Improved and notes specimens from Gregory in 1884.

As shown by the above history, this variety is one of the most improved and best bred strains of the New England Eight-rowed flint. It was first catalogued by J. H. Gregory, of Marblehead, Massachusetts, in 1877. In a letter to the authors Mr. Edgar Gregory gives the following description of the 1877 Longfellow yellow field corn: "This is the largest kerneled variety of yellow field corn I have ever seen matured in Massachusetts. The ears are remarkably long and well filled, the variety is the final result of careful selection

* Lit. cit., p. 36.

and improvement for forty-five years." In the Gregory seed catalogue for 1878 the following statement appears: "Some of the ears grew 15 inches long and oftentimes two or more specimens grew on a stalk. It is the largest kerneled variety of field corn that I ever found safe to plant in the latitude of Massachusetts." The following detailed history was received from Mr. Edgar Gregory:

"We have just received a letter from Mr. Longfellow, the grandson of the originator of the Longfellow Field Corn, which reads as follows: 'In reply to your letter at hand would say that the originator was my grandfather, Samuel Longfellow of Newbury, Mass., who afterwards moved to Groveland. The original stock was the King Philip variety which was combined with two other varieties, one of which possessed remarkably long ears, the other much larger kernels than the King Philip. Then with a certain type in his mind, by careful ear selection for many years he established a variety which became very uniform in shape, color, etc. This corn acquired a local prominence and was called to the attention of the late J. H. Gregory, who placed it on the market in his catalogue, as one of his

FIG. 16. a, Robertson (yellow early dent); b, Mercer (yellow late flint); c, King Philip (red late flint); d, Longfellow (yellow late flint).

specialties, giving it the name of the Longfellow corn. This corn has been kept free from mixture with other varieties for more than sixty years.'"

In 1884 the pioneer seed firm of Northrup, Braslan, Goodwin Company, of Minneapolis, Minnesota, catalogued it and gave the following description:

"This is an 8-rowed yellow flint variety, the result of careful selection in a family of Massachusetts for 45 years. The ears are from 10 to 15 inches long; 1½ to 1¾ inches in diameter; are well filled out to the extreme end of the cob, which is small; kernel large and broad. This corn is well adapted to the Northwest and is said to be the heaviest yielding corn grown in Massachusetts."

Distribution.—Massachusetts and the New England States, Canada, and the northern tier of the western States.

Characteristics.—Late flint; ears 8 to 12 inches long, quite slender; eight rows of kernels; color lemon yellow; cob white; stalks 5½ to 6 feet; ears 22 inches from ground; suckers numerous.

SMUT NOSE (REDDISH YELLOW LATE FLINT)

History.—The Smut Nose is a corn of uncertain origin. There is very little in the earlier descriptions of New England corns to positively identify the variety. Some are of the opinion that it is a cross between a red type, such as the King Philip, and the New England Eight-rowed yellow. However, there is no direct proof to substantiate this, and it is just as likely to have been a color form or variant of either of the above types. It is classified in Sturtevant* as synonymous with the Red Blazed. The synonym "Smut Nose" is mentioned as coming from the Canadian Experimental Farms in 1894. It is described as being a color form of the New England Eight-rowed. Kernels yellow on butt end of ear, red splashed, mostly on one side of tip portion. Reported 6 to 7 feet tall at Ottawa. It was catalogued and offered by Northrup, King & Company in 1898, with the following description: "Yellow flint corn, blazed with red at end of ear; ears large and round. This is a very early variety and a great favorite in many localities."

Distribution.—New England, Canada, and northern tier of States, especially Wisconsin, Minnesota, North Dakota, and eastern Montana.

* Lit. cit., p. 38.

Characteristics.—Late flint; ears 8 to 10 inches long, slender; eight rows of kernels; kernels yellow with crowns sometimes red; splash of red toward tip of ear; cob white; stalks 5½ to 6 feet high; ears 20 inches from ground; suckers numerous.

KING PHILIP (RED LATE FLINT)

It has been said that King Philip is a variety of corn that the Puritans took away from the old Indian chief of that name at the time of King Philip's War in 1675. History reveals that they took possession of 1,000 acres of corn which was harvested by the English and disposed of according to their direction. However, there is no proof that this corn was of a certain type and that it was named King Philip.

Sturtevant* says, in describing King Philip corn: "A name applied to the copper-yellow or copper-red forms of New England Eight-rowed and its variants. It occurs as a variant, or as an atavism in most crops of New England Eight-rowed flints, and is often grown as a separate variety under its various forms." Plants are reported to be 6 to 8 feet tall and it is extensively catalogued by seedsmen.

Enfield** says that the King Philip and some other improved sorts have probably been derived from the New England Eight-rowed.

Brown*** describes this corn as an 8-rowed blood red variety. "Plants and ears," he says, "are about the same size as the 8-rowed yellow." He gives the following description of the King Philip, so called after the chief of the Wampanoags of that name, from which tribe the seed was originally obtained:

"The ears, which contain only 8 rows, are longer, and the cobs smaller, and the grains larger than those of the golden Sioux, and it will yield about the same quantity of oil. It is a hardy plant, much esteemed in New England as a substantial article of food where it has been cultivated from times anterior to the landing of the Pilgrims.

"From this variety a number of superb kinds have been obtained, among which are a beautiful 10 and 12-rowed hybrid from the golden Sioux and the well known Browne corn improved by John Browne

* Lit. cit., p. 37.

** Lit. cit., p. 61.

*** Lit. cit., p. 43.

of Long Island (in Lake Winnipissiogee). The latter variety was produced by cultivating selected ears for a succession of years of the King Philip corn with small butt ends, the second ripe in the field, and taken from stalks which bore more than two ears each. The grains of this corn are large, the cobs small, and the ears usually from 10 to 13 inches in length, with only 8 rows. It ripens a little later than the golden Sioux and is very prolific, the greatest crop per acre that has yet been raised being 136 bushels, weighing in the ear 9,520 pounds, or 70 pounds to the bushel, and 58 pounds when shelled.

Mention of the Improved King Philip or Brown corn is made in all the Patent Office reports (Agricultural Division) from 1850 to 1860. The following history from Brown* himself is interesting. It is unfortunate that he neglected to speak of the color.

"It has been my rule, for a succession of years, to select well filled ears of the 'King Philip' or Northern eight-rowed yellow corn, with cobs having small butt-ends, of good length as well as uniform size; the second ripe in the field, and taken from stalks bearing more than two ears to each. The result has been, I have produced a variety of corn, apparently fixed in its character, which sometimes bears my name, (Brown corn,) having large kernels and a small cob, varying from 10 to 13 inches in length. The largest crop I have ever raised was 136 bushels to the acre, weighing in the ear 9,520 pounds, or 70 pounds to the bushel, and 59 pounds per bushel when dried and shelled."

In another report Brown says he began farming and improving corn in 1817.

Enfield** in his description of varieties says: "King Philip.—An eight-rowed yellow or copper-colored corn, so called from the celebrated Indian chief of that name It bears a long ear with a small cob, and the kernel is larger than that of the Golden Sioux. It is a hardy variety, ripening early, and very productive. It is much esteemed in New England, where it has been long cultivated, and is regarded by many as one of the best field sorts in use."

Professor Sheppard of the North Dakota Experiment Station writes:

"I find that it was known to my father when he was a young man and to the older men among our neighbors in southern Iowa. They grew it there at an early day for that generation, and they all knew it in Indiana, Ohio, and the eastern states, when they were

* Report of the Patent Office for 1853, p. 113.

** Lit. cit., p. 61.

boys. If those men were now living they would be 90 to 100 years old so that I would say that King Philip was a very well established variety 75 years ago. I know of no other variety of corn that has an established history so old as King Philip. Probably the peculiar color of the grain has helped to identify it."

Substantiation of Professor Sheppard's statements can be found in the U. S. Patent Office reports for the period from 1850 to 1860. From these it may be inferred that the Office distributed a quantity of King Philip over the entire region then growing corn. Several pages in the 1854 report are given to letters from farmers, which frequently begin like this: "Early last spring I received from the Patent Office a small quantity of what was called Improved King Philip or Brown corn." Most correspondents reported favorably. In connection with Professor Sheppard's statement, one report in the 1855 volume is interesting. It is the statement of G. P. Walker,* Decatur County, Iowa: "I planted the 'King Philip' corn, which I received from the Patent Office, in my richest ground, in a very careful manner, on the 9th of May. . . It was fully ripe before the middle of August, and the yield was abundant. Having distributed this corn liberally among my neighbors, both in Southern Iowa and Northern Missouri, to a distance of 60 miles, I am confident it will be thoroughly tested the present year."

Director Brooks, of the Massachusetts Agricultural Experiment Station, says: "All the strains that I have seen for a great many years of the King Philip have been red. However, I believe that in the early times the variety was mixed yellow and red, i. e., some ears would be yellow, others red. I am not perfectly certain, however, that this was the case, and evidently even if it was, modern breeders of the variety have selected until it comes uniformly red."

There appear to be some variants in the color form attributed to this corn. Hunt** classifies King Philip as a yellow corn and reports that it is a very satisfactory type of New England flint, while Plumb*** mentions it as copper colored or copper red. Northrup, Braslan, Goodwin Company described King Philip in 1884 as

* Report of the Patent Office for 1855, p. 172.

** Hunt, Thos. F. Cereals in America, p. 168. New York, Orange Judd Co.

*** Plumb, Chas. S. Indian Corn Culture, p. 29. Chicago, Saunders Pub. Co., 1895.

follows: "A very early variety of field crop; matures in three months from planting. Ears 10 to 12 inches long, uniformly eight-rowed. Kernels dark copper red, rather large. Stalk six feet in height, producing one or two ears. A fine variety for replanting where others fail to come up." The corn is described now by practically all seedsmen as having a copper color.

Distribution.—New England, Canada, and northern tier of States.

Characteristics.—Late flint; ears 8 to 12 inches long, slender; eight rows of kernels; color red or shades of red; cob white; stalks 5 to 6 feet; ears 18 inches from ground; numerous suckers.

OTHER LATE FLINTS

History.—Over forty other varieties and synonyms of the above varieties have been tested by this station. As a rule the seed of the New England flints does not give very satisfactory results the first year except for silage. Among the most promising of the New England corns are the Improved Early Canada, furnished by the Maine Seed Growers' Association, and the Davis corn, furnished by Mr. Perley E. Davis of East Granby, Massachusetts. In a letter to the authors, Mr. Davis gives the following history of this corn:

"I procured this corn some ten years ago locally. It had been produced from a cross between a type of Longfellow and a small-cob early variety, and had been selected and kept pure by a careful farmer. I have practiced selection to eliminate certain faults, and bred for an ear to average 9½ inches in length, a broad, deep, thick kernel, of high yielding power and a high percentage of seed ears. I practice ear to row test and a breeding plot. In 1910 I won for high yield of actual food value, Bowker's Grand Prize of $500 over all corns grown in the northeast, and many first prizes for quality year by year."

In 1910 the Bowker Fertilizer Company of Boston, Massachusetts, conducted an acre corn test in New England. Mr. Davis with this corn won the first prize and produced 126.8 bushels of dry ear corn, calculated at 70 pounds per bushel of shelled corn. The test was conducted in a thoroughly scientific manner and furnishes some extremely interesting material on northern corn. The following statement is from a summary of the results:* The corn prize was awarded to Mr. Davis' yield of 127 bushels of yellow flint, over 133

* Book of the Bowker Corn Contest, Boston, Mass.

bushels of white dent, because it contained greater food value. The protein, fat, sugar, etc., contained in the crop of 127 bushels of yellow flint (equal to 103 bushels of crib-dry shelled corn) grown by Mr. Perley Davis, was 4,934 pounds, while the same food elements contained in the 133-bushel crop of white dent (equal to 86 bushels of crib-dry shelled corn) was 4,102 pounds. The Davis corn has a medium stalk, a rather large ear, with broad kernel, is eight-rowed, and light copper-colored.

NORTHWESTERN DENT (WHITE CAP RED SEMIDENT)

Synonyms: Smoky Dent, Strawberry Dent, Early Red Dent.

History.—Northwestern Dent is a corn of very doubtful origin. There are two theories concerning it; one that it is an old Indian corn which was raised very likely by the Indians of the Ohio River Valley; the other that it is a cross between a red flint corn, similar to King Philip, and a white dent. Efforts have been made in this State to produce such a type of corn by making such a cross but as yet are failures. Its habit of growth, stalk, and leaf characteristics would indicate Indian origin, but there is no evidence to substantiate such a theory. However, it is possible that early Ohio agricultural history might throw some light on this point. A red corn under varying names has been used as a pioneer sod corn over much of the corn belt. Mr. Henry Field, of Shenandoah, Iowa, states that an early corn, sometimes called Ninety-Day Red or Early Bloody Butcher, was brought into southwestern Iowa from Illinois in the grasshopper year of 1875 by farmers who had to replant their corn in June and July, after the grasshoppers had eaten off the first planting. Many of the settlers of northern Iowa and South Dakota have informed the writers that they used to raise a red semident corn on sod. It was early considered the only corn adapted to new lands. The corn was described as having ears from 8 to 9 inches long; rather a smooth dent with red kernel, sometimes wholly red and sometimes with a white streak in the top of the kernel, and always with a white cob. In substantiation of its hybrid origin, some have called attention to its tendency to produce flint ears which somewhat resemble King Philip. In this State, however, its tendency is all towards producing this type of ears, and the writers have not found in their experiments nor have they met any farmers

who have found ears which tended to revert to the white color. The lack of such ears is taken by the writers as partial proof that it is not of hybrid origin, or that the red character was recessive in the cross and only recessives were used in the early selection.

FIG. 17. Showing acclimated variety in comparison with more southern type.

On the left, Northwestern Dent from southern South Dakota; right, Northwestern Dent from Bismarck, North Dakota.

For fifty years there has been grown in Minnesota, especially in the southern part of the State, a red dent corn which has been grown under the name of Bloody Butcher, sometimes Smoky Dent. Mr. A. J. Bush, of Homestead County, Minnesota, states that "this corn was brought into that county by settlers from Indiana over fifty years ago. It was called Smoky Dent and was grown in southern Minnesota and northern Iowa. It proved better adapted to the new country." As far as Mr. Bush's recollection goes the type has not changed. "It is fully as early as the flints and has made as high as 75 bushels per acre in the early days on the old lake bottoms."

In 1891 Mr. J. W. Burch, a farmer near Bismarck, brought back from a visit to his old home in Monroe County, Indiana, about ten miles north of Bloomington on White River, a little seed of a small red dent corn which was very extensively used there for late replanting. He planted it the next spring. In the fall Mr. Will visited the Burch farm, inspected the corn, and picked some fifteen or twenty ears which were the nearest ripe. Very shortly after all the rest of the corn was very severely frozen, only the few ears taken home and dried by Mr. Will germinating. Mr. Will planted the seed himself the next year and the year after. The second year he raised enough seed to plant thirty acres. This seed Mr. Burch planted in the spring of 1895 and harvested a good crop in the fall, which he contracted to Mr. Will.

Professor Sheppard, of the North Dakota Experiment Station, in a letter to the authors, says, "A type of corn similar to the North Dakota Dent was grown commonly by those who grew corn twenty years ago which was the first that I knew of the corn growing in this community. I have heard a great many stories as to what its origin is, but do not know of any that I consider entirely dependable. From the appearance of it, it must carry some flint blood."

Mr. Still Wilkins, of Circle, Montana, says that he "grew for thirty years in Chippewa County, Wisconsin, a corn almost identical with what is known as Northwestern Dent in this state. It was known in Wisconsin as Strawberry Dent and was considered very hardy and productive."

Mr. Will offered it first in his 1896 seed catalogue with the following description: "After many years of experimenting, great expense and much labor, we have at last succeeded in securing a

FIG. 18. a, Northwestern Dent (white cap red semident); b, Minnesota 23 (white cap yellow semident); c, Minnesota King (yellow semident); d, Rustler (early white dent).

Dent corn that will mature in North Dakota and the Northwest generally. Northwestern Dent is the result of acclimation and careful selection and improvement of what is known in some localities as the 'Butcher' corn. It follows the Gehu and Improved Pride of Dakota very closely. . . . Northwestern dent is no experiment. . . . It is what many Northwestern farmers have been looking for these many years." Northrup, King & Company in 1901 catalogued Northwestern Dent, or Bloody Butcher, stating, "This variety is in a class by itself, being a Red Dent sort. . . . It is a great favorite in North Dakota. There are two strains of this 'red dent' corn, both having been sold under the name of Bloody Butcher. . . ."

Sturtevant* makes mention of four Bloody Butchers,—two by their proper names and two as synonyms. One comes from the U. S. Department of Agriculture, with ears 10½ inches long, ten-rowed, broad, rounded, crease-dented kernels, deep orange-red or blood-red with yellow dent, ear stalk small to medium, cob red. The other is from the Illinois Experiemnt Station, mentioned in 1889. The season is given as 125 days in Iowa. The kernel is described as deep, long-dimple dented, red with yellow dent, ear stalk medium, cob white.

Distribution.—Northwestern Dent is now widely disseminated and is no doubt more extensively grown than any other variety in the Northwest. It is extremely hardy, and while it has a rather shallow kernel and large cob, thus having a comparatively low shelling percentage, it is a very rugged, hardy corn. It is found in central and northern Minnesota, North Dakota, northern South Dakota, and Montana. This variety probably leads in acreage planted in North Dakota and Montana.

Characteristics.—Semident; ears 6 to 8 inches long, gently tapering; coarse expanded butts quite common; ten to fourteen rows of kernels; kernels red with white creased dent; cob white; stalks 4½ to 5½ feet; ears 20 inches from ground; normally produces more suckers than any other semident or dent variety.

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* Lit. cit., pp. 53, 73.

MINNESOTA 23 (WHITE CAP YELLOW SEMIDENT)

History.—Mr. C. P. Bull, associate agronomist of the Minnesota Experiment Station, gives the following history of the Minnesota 23 corn: "In 1893 a farmer in Polk County, Minnesota, sent to the University farm a small amount of seed of a variety which had for some time been grown by him. It was invoiced in the serial order and given Number 23. At the University farm, St. Paul, this seed was tested for three consecutive years, in the variety test plots, with other varieties from other sections of the state. On account of the low yields from central and southern Minnesota, No. 23 was discarded. In 1905, the writer, looking for an early maturing variety of corn of high yielding power, discovered the worth of Minnesota No. 23. In the spring of 1906, all the original seed was planted in

FIG. 19. a, Northwestern Dent (white cap red semident); b, Minnesota 23 (white cap yellow semident); c, Minnesota King (yellow semident); d, Rustler (early white dent).

an increase plot, and from the resulting crop ears were selected for breeding purposes. During the succeeding years, the corn has been very carefully selected and bred according to the broad breeding method. At the same time seed from carefully selected ears was planted the following years in a breeding plot. In 1908, there was sufficient seed to offer it in limited amounts to the farmers of northern Minnesota. The reported yields were so satisfactory that it was decided to offer it for wider distribution in 1909. The experimental data at the University farm show that this corn, when planted on May 10th to 15th, will ripen the first week in August. The average yield of dry shelled corn per acre has been 41.6 bushels, and 1.48 tons of stover. This corn is replacing flint corn in the northern part of Minnesota. It is also being substituted for Northwestern Dent by many growers."

Distribution.—Northern Minnesota, North Dakota, and Montana.

Characteristics.—Semident; ears 6 to 8 inches long, gently tapering; twelve rows of kernels; kernels white cap with light yellow sides; cob white; stalks 4½ feet to 5 feet; ears 22 inches from ground; few suckers.

MINNESOTA KING (YELLOW SEMIDENT)

Synonym: Ardmore.

History.—This corn is described in most seed catalogues as a cross between a flint and a dent. As to just exactly when the cross was made and who made it, definite information is lacking. Professor Sheppard says it was originally introduced by Northrup, Braslan, Goodwin Company and at one time had great favor in North Dakota. According to Mr. Jesse Northrup of the above firm it is a cross between the Mercer and some dent. Because the corn is so remarkably fixed in its type and shows practically no tendency to produce flint or dent types, it seems rather doubtful to the authors that this is the case. It may be spoken of as a distinct semident with a broad square kernel. It may possibly be related to the Hickory King corn of the Ohio River Valley and south. The earlier seedsmen of the Northwest catalogued this corn, and prior to the introduction of Northwestern Dent it was one of the leading dent types. It is not so widely grown, however, at the

present time but is being replaced by the Northwestern Dent. Like the Northwestern Dent it is an extremely hardy type and withstands the northwestern conditions very well. It is listed by Sturtevant with the following description: "Ears 7 to 8½ inches long, rounded at butt; 8-rowed; somewhat distichous; sulci distinct. Kernels smooth, broad, and broad at base. Crease-dented light orange with yellow cap; cob white. Plant reported as six feet tall, and season varying from 102 to 118 days."

In a report of variety tests of corn, in 1888, the Pennsylvania Station says:* "Minnesota King ripened with the flint varieties. Though early, it did not produce a heavy yield. The stalks were small, and the ears were filled with closely-set, good-sized kernels." Their accession book shows that the corn came from the Northrup, Braslan, Goodwin Company, Minneapolis. In 1890 the above-named firm introduced the corn with the following description:

"Minnesota King—The distinguishing characteristic of the Minnesota King corn is its sureness as a cropper. There are other varieties equally prolific and of as good quality but there is no good sort that can be relied upon to mature as certainly as this. It has been grown in Dakota for the past seven years, and while during that time other varieties have been caught by frosts, ruined by drought, or injured by excessive rainfall, the Minnesota King, regardless of the weather, has kept right on growing and always made a crop, and a good one at that. It stands today, pre-eminently the king of all field corn.

" . . . In appearance Minnesota King is remarkably distinct, being half yellow dent with fair sized ear, eight-rowed, small cob, grain large, very broad and of extremely rich golden color. It is now a fixed variety, and our seed has been selected with great care and grown the past season in Hand County, Dakota, near the Beadle County Line.

"For ability to endure extremes of heat and cold, flood and drought, it has not its equal."

The corn has been quite widely grown in North Dakota, but has never been susceptible of great improvement. Its chief asset is its hardiness.

Distribution.—Minnesota, North Dakota, eastern Montana, and South Dakota.

Characteristics.—Semident; ears 5 to 7 inches long, cylindrical

* Rept. of Pennsylvania Exp. Sta. for 1889, p. 33.

or slightly tapering; eight rows of kernels, yellow with white creased dent; cob white; stalks 5 to 6 feet; ears 24 inches from ground; few suckers.

RUSTLER'S WHITE DENT (EARLY DENT)

History.—This corn was first introduced by the Northrup, Braslan, Goodwin Company of Minneapolis, Minnesota, in 1888. They give the following description and history of the variety in their catalogue of that year:

"This valuable corn was obtained from a few kernels sent us in the autumn of 1884 by a Dakota farmer who stated that he had matured it in that territory for seven successive years, and that it was the only corn anywhere in his section that could show such a record. We were so much pleased with the results of the first year's trial that we saved the entire product and now offer it to our patrons with full assurance that for early ripening, great yield, compact growth of ears, it is one of the best, and admirably adapted to this climate."

The correspondence in our possession seems to indicate that the origin of the Rustler's White Dent corn was an early white corn taken from the Indians to the northeastern part of North Dakota about thirty-five years ago. However, the evidence is not sufficient to justify a positive statement. Rustler's White Dent is disseminated widely over the Northwest and is considered the foundation stock of the early white dent corns.

At the Minnesota Experiment Station and at the Brookings and Highmore stations in South Dakota, as well as at experiment stations in this State, this variety ranks very high in yield. Sturtevant states that it was introduced by the Northrup, Braslan, Goodwin Company of Minneapolis.

Distribution.—Northern Minnesota, North Dakota, northern South Dakota and eastern Montana.

Characteristics.—Early dent; ears 6 to 7 inches long, slowly tapering; twelve to sixteen rows; kernels white and rather smooth; cob white; stalks 5 to 5½ feet; ears 18 inches from ground; few suckers.

PIONEER WHITE DENT (EARLY DENT)

History.—The following information was furnished by Mr.

FIG. 20. a, Pioneer White Dent (early dent); b, Brown County Dent (yellow early dent); c, Square Deal (yellow early dent); d, Eiker's Yellow Dent (early dent).

Oscar H. Will, of Bismarck, North Dakota, who introduced Pioneer White Dent:

"This is probably a selection from the Rustler. The seed was secured about eight years ago from Dr. B. F. Schuster, of Wyndmere, Richland County, North Dakota. At that time it had been raised by him for twenty years continuously, and he did not know where he had gotten the seed. I raised it, selecting the best for several years in the nursery, before we gave out any of the seed on contract, since which time I have generally furnished the contractors from my nursery patch, up to last year."

Distribution.—North Dakota and eastern Montana.

Characteristics.—Early dent; ears 6 to 8 inches long, slowly tapering; fourteen to sixteen rows of kernels; kernels white with occasional shades of pink on tips of ears; cob white; stalks 5 to 6 feet; ears 24 inches from ground; suckers few.

DISCO PRIDE or BROWN COUNTY DENT (YELLOW EARLY DENT)

History.—Prof. W. A. Wheeler, manager of the Dakota Improved Seed Company, Mitchell, South Dakota, introduced this

FIG. 21. a, Pioneer White Dent (early dent); b, Brown County Dent (yellow early dent); c, Square Deal (yellow early dent); d, Eiker's Yellow Dent (early dent).

corn. It was first catalogued by that firm in 1909 with the following description:

"In 1906 we first ran across a variety of corn in Brown County which had made a good record for yield and earliness. It has been grown there and has matured satisfactorily for the last 18 or 20 years. It has been tested at the Highmore Experiment Station where it yielded between 45 and 50 bushels to the acre. In 1907 at the same station this same variety outyielded all other varieties, and showed a drouth resistance second to none. In fact there was no other corn at the Highmore station in 1907 that was nearly equal to this in resisting the dry weather. In season it is earlier than either the Northwestern Dent or the North Dakota Golden Dent. In type it resembles the Pride of the North and the North Dakota Golden Dent. It has not been selected for uniformity of type and shows quite a variation in color and shape of kernel. This, however, does not injure it in any way when it comes to producing a good yield of corn under adverse circumstances. We believe that this corn planted in the northern part of South Dakota or in North Dakota is the safest proposition in corn that can be secured. The seed from which our stock was grown in the past season was secured from Brown county and has been grown in Brown county for the last 18 or 20 years continuously."

Distribution.—This corn was very largely raised in northern and western South Dakota and has given good returns over the Yellowstone watersheds in this State.

Characteristics.—Early dent; ears 6 to 8 inches long, slowly tapering; twelve to fourteen rows of kernels; color yellow with tendency towards copper-colored seed; cob red; stalks 5 to 6 feet; ears 22 inches from ground; suckers few.

WILL'S SQUARE DEAL (YELLOW EARLY DENT)

History.—This is a very early, hardy, northwestern corn. In 1900 Mr. Oscar Will sent to Ohio and secured a small quantity of seed which was catalogued in that state as the "earliest dent corn on earth." It proved to be early enough at Bismarck, North Dakota, to mature about half the ears, which were very large, growing on a stalk about 8 feet high. After six years of breeding, Mr. Will offered this corn with the following description in his 1906 catalogue. "Six years ago last spring the writer secured a small package of yellow dent corn which was claimed to be the earliest corn in cultivation. It proved to be early enough to mature about half the

ears, which were very large, growing on a stalk about eight feet high. We have been selecting the best and earliest type each year since, until we have what we believe to be and claim is the earliest dent corn on earth. The ear stalks have been greatly reduced in size. The peculiarity of this corn is that we have bred the ear to be quite high on the stalk. It is a very satisfactory yellow dent corn."

This corn is widely disseminated throughout eastern Montana and has proved itself to be a very satisfactory variety.

Distribution.—North Dakota and Montana.

Characteristics.—Early dent; ears 6 to 8 inches long, slowly tapering; twelve to fourteen rows; kernels yellow with red cob; stalks 5 to 5½ feet; ears 18 inches from ground; few suckers and fine leaves.

ROBERTSON'S YELLOW DENT (EARLY DENT)

History.—This is a very interesting type of corn and presents peculiar adaptation. This corn was originated by Mr. John Robertson of Hot Springs, South Dakota. It was furnished us with the following history of the variety:

"I have tried several kinds during the 22 years that I have lived on this place, but none ever equal to this yellow corn. My altitude is 4,200 feet. It will get ripe every year. Does not sucker and shells heavy in comparison with the weight of the cob. It was grown here when I settled in this county, and I have bred it for 22 years. In this dry country it is something to have a corn that does not sucker, so that a hill will produce two stalks, and yet have moisture enough to mature it."

Mr. Robertson has selected this corn for earliness and depth of kernel. The adaptation which has taken place is a very short ear with a very deep kernel. Because of the fine stalks it is better adapted to being cut and bound with the grain binder and being threshed. The kernel is fully as deep as any of the Middle West corns but is smaller, and the ear is only about four inches in length.

Distribution.—The Black Hills region of South Dakota, above an altitude of 3,500 feet.

Characteristics.—Early dent; ears 4 to 6 inches long, cylindrical in shape; twelve to fourteen rows of kernels, shoe-peg shape; yellow color with red cob; stalks 3½ to 4½ feet; ears 12 to 18 inches from ground; few suckers; few stalks and leaves.

EIKER'S YELLOW DENT (EARLY DENT)

History.—This is the most widely known and generally distributed corn which has so far originated in this State. Mr. E. Eiker settled on the Huntley irrigation project and planted his first corn in 1909. He secured the seed from Mr. A. H. Wright who had brought it from a northern county in Iowa seven years before and had been selecting and planting the earliest maturing ears. It is not known that the original corn was of a distinct variety but it is described as an early yellow dent similar to Minnesota 13. Mr. Eiker has bred the corn and exhibited it at the State and county fairs for the past six years. It won second in competition with corn from North Dakota, South Dakota, Minnesota, Oregon, Washington, Idaho, and Wyoming. It has won first in its class and sweepstakes at the Montana fair for the past six years. It is not as early as Northwestern, Rustler, or Square Deal, but it is much earlier than the eastern types of Minnesota 13, which it greatly resembles.

Distribution.—Upper Yellowstone Valley in Montana.

Characteristics.—Early dent; ears 6 to 8 inches long, slowly tapering; fourteen to sixteen rows of yellow kernels with red cob; stalk 5 to 6 feet; ears 18 inches from ground; few suckers.

OTHER EARLY DENT VARIETIES

Two varieties belonging to this class which might be mentioned are Dakota Sunshine Dent and North Dakota Agricultural College Golden Dent.

The Sunshine Dent was introduced by Mr. Will into North Dakota in 1904 with this description: "This corn grows a little taller than the Northwestern Dent, yields heavier, and requires about the same length of time to mature. . . . The color is a rich golden yellow." In Montana tests we have found this variety to be later than the Northwestern Dent.

The North Dakota Agricultural College Golden Dent is described by Professor Sheppard as being a smaller edition of Pride of the North. Its improvement was started at the North Dakota Station in 1900. Its behavior under Montana conditions is not promising.

MINNESOTA 13 (YELLOW LATE DENT)

History.—Mr. C. P. Bull of the Minnesota Experiment Station has given the following description of this corn:

"Minnesota 13 was obtained by University Farm, April 1st, 1893, from De Cow & Company, St. Paul. This was in the early days of the Experiment Station work and the seed was purchased simply for planting for corn crop at the station. In seeking such a variety, a seed that would be as desirable as possible, judging from uniformity and character of the kernels, was purchased. The stock of seed was invoiced as No. 13. The variety matured early and yielded well. As near as could be determined, it was primarily of Pride of the North stock. This, however, is not certain as few, if any, farmers took pains to keep corn pure and nearly all seed

FIG. 22. **a, Triumph (yellow late flint); b, Minnesota 13** (yellow late dent).

corn was bought as yellow dent or white dent, and flint, color being the identification mark.

"In 1897, after four years production at University Farm, ears were picked out for a centgener (ear to row) test in a breeding plot. The prime object at this time was to get the highest yielding individuals for continuing the breeding plot and to secure at the same time earliness in maturity. In 1902 considerable progress had been made and it was deemed wise at this time to pay more attention to the uniformity of character and to select for type as well as for better yield and maturity. Careful score card notes were therefore taken and selection rigidly made. . . .The first distribution of Minnesota No. 13 corn to the farmers of the State was made in 1897."

Distribution.—Throughout the northwestern States.

Characteristics.—Late dent; ears 6 to 10 inches long, slowly tapering; twelve to sixteen rows of kernels; kernels yellow with red cob; stalk 5½ to 6½ feet; ears 18 inches from ground; few suckers.

FIG. 23. a, Triumph (yellow late flint); b, Minnesota 13 (yellow late dent).

LANSING (YELLOW LATE DENT)

This is a local variety which is grown around Miles City and is named after the man who originated it. The source of the seed

is unknown, but it has been grown on dry land near Miles City for the past twenty years. It has a broad kernel bordering on the semi-dent yellow kernel type. The stalks average about 5 feet in height; ears are borne about 20 inches from the ground, and the variety is about as early as the Northwestern Dent.

YELLOWSTONE WHITE DENT (LATE DENT)

This variety was originated by Mr. Walter Hawley at Rosebud, Montana, and is of hybrid origin. It is larger and later than Rustler or Pioneer White Dent. It has been grown mostly on the irrigated land.

DISCO EIGHTY-FIVE DAY WHITE DENT or PAYNE'S WHITE DENT (LATE DENT)

This was first catalogued by the Dakota Improved Seed Company in 1911 with this description:

"This variety of early white corn has been named after the man who has bred and grown it for a number of years near Lebanon, South Dakota. Mr. Payne also grows Brown County Dent, but this white corn he calls his own corn and has a right to be proud of it. In testing with Brown County it appears to be as good a yielder and practically as early as the Brown County corn. In drouth resistance it has not been compared with the Brown County Yellow Dent in other localities so no general statement can be made, but on Mr. Payne's farm it has stood the test of all conditions that have come to it during the entire time it has been grown by Mr. Payne. This variety won first premium on white corn in the northern district of South Dakota at the state corn show in 1908 and 1910."

This variety of corn is being grown in eastern Montana. It is a little later than Pioneer White Dent or North Dakota strains of Rustler. It has won several prizes at Montana corn shows and appears to be worthy of a place in varieties recommended for Montana.

The following varieties are prominent in the North Central States and are included here as they are early maturing among corn varieties where grown. In Montana tests they have not proved as valuable as the native varieties.

PRIDE OF THE NORTH (YELLOW LATE DENT)

History.—Pride of the North* was originated by the veteran corn grower, H. J. Goddard, of Fort Atkinson, Iowa. The start came from seed sent out by the U. S. Department of Agriculture in 1870. Mr. Goddard began breeding this corn in that year and in 1876 sold his crop of seed to the Hiram Sibley Seed Company of Chicago. This company named it Pride of the North and gave it wide publicity. Mr. Goddard has won many prizes with this corn and for many years it was the only distinct variety of northern yellow corn. It was later known as Sibley's Pride of the North and forms the foundation stock for many of the northern corns.

Distribution.—Northern Iowa, Minnesota and South Dakota. It is not promising for Montana except for silage.

WISCONSIN NO. 7 or SILVER KING (WHITE LATE DENT)

The Wisconsin Experiment Station describes this corn as follows:

"Wisconsin No. 7, Silver King, is a white dent corn with medium sized ears. The kernels are medium deep and have a rather medium-rough dent. The stalks reach a good height and are very leafy, hence the excellence of this variety for silage purposes.

"This corn was originated by Mr. H. J. Goddard of Fort Atkinson, Iowa. Professor Moore, of this station, obtained a sample in 1904 and introduced it into Wisconsin. Ear to row selection was made on it and the type was developed along the lines stated above. The corn is adapted to southern Wisconsin."

WISCONSIN NO. 12 or GOLDEN GLOW (YELLOW LATE DENT)

The Wisconsin Experiment Station has furnished the following statement regarding Wisconsin No. 12:

"Wisconsin No. 12, Golden Glow, is a cross between the Early Yellow Dent and Toole's North Star. . . .

"Golden Glow is not such a heavy producer as the Silver King. The ears are somewhat smaller than the latter and the plant itself is finer throughout. The ears are yellow in color, deep yellow being the standard color. The cob is a bright cherry red in color and the dent of the kernels should be what is termed a crumpled dent."

* This information was contained in a letter to the authors from Mr. Goddard.

Part IV. Climatic

Under this head are presented data and discussions on the temperature conditions in the different parts of Montana. Also reference is made to the hours of sunshine, the moisture requirements and the hail resistance of corn.

TEMPERATURE CONDITIONS IN MONTANA

In discussing the influence of temperature on corn growing Frear and Caldwell* say: "The facts show that at all times both day and night in our climate the temperature is the principal climatic factor affecting the growth of corn."

While the authors recognize that such features as the relative

FIG. 24. Field of irrigated corn in the lower Yellowstone Valley, Richland County. The variety is Minnesota 13 and shows such development as is ordinarily seen in southern Minnesota and northern Iowa. The rape was sown at the time of the last cultivation of the corn.

* Relation of Meteorological Conditions to the Development of Corn. Report of Pennsylvania Exp. Sta. for 1889, p. 229.

day and night temperatures, the number of hours of sunshine, etc., exert an important influence, it has been decided to present data showing the length of the frost-free period and the average temperature during this period, in the belief that these more clearly show the corn-growing conditions in different parts of the State than would a comparison of other climatic factors.

The length of the frost-free period for each year was determined by finding the number of days from the last frost in the spring (temperature below 32°) to the first frost in the fall. The average given was found by taking these dates for the ten years ending with the season of 1912 and finding the average date in each case.

In comparing the temperature conditions prevailing in different sections of the State, the number of heat units during the frost-free

FIG. 25. Silage corn grown under irrigation in the Bitter Root Valley near Missoula. This corn made ten tons of silage per acre. Typical of the lower intermountain irrigated valleys. Altitude 3,198 feet.

FIG. 26. This field is fairly typical of the manner of growth of the adapted early dents and semidents on dry land in the plains east of the mountains. Note that the stalks are not higher than a man's head and the foliage is fine and leafy.

FIG. 27. Field of Gehu Flint on dry land, Flathead Reservation. Yield estimated at 35 bushels per acre. Typical of the non-irrigated intermountain valleys of medium elevation.

period was used. By heat unit is meant a degree of temperature above 40 for one day. The number of degrees above 40 for each day of the frost-free period was added for each of the ten years ending with 1912 and the average number of heat units was determined for each locality.

Objection might be urged against the basis of 40 degrees, as corn grows very slowly at temperatures down near this point. While the contention may be well taken, yet certain hardy varieties make growth under conditions differing widely from those in the corn belt, and for purposes of comparison the data figured in this way ought to be of value.

A study of these data, given in Table II, shows wide variation in the length of the season and in the degrees of temperature at different points. There is very little relation between the length of the frost-free period in any locality and the total number of heat units at the same point. Kalispell, in Flathead County, shows 148 days frost-free on the average. This is the longest frost-free period of any point studied, and yet Kalispell stands fourteenth in the number of growing heat units. Miles City as compared with Kalispell has two days less of frost-free period and 51 per cent more heat units.

Missoula, Helena, Havre, Chinook, and Hamilton, widely separated in point of location in the State, and with considerable difference in the length of the frost-free period, all show practically the same number of heat units. This fact is of interest and makes possible the comparison of the growing conditions in different localities.

For purposes of comparison the heat units at three points outside of Montana were determined. It was found that Des Moines, Iowa, located in the heart of the Central West corn belt, showed 4,982 heat units; Minneapolis, Minnesota, where certain types of corn are generally grown, 4,093 heat units; and Bismarck, North Dakota, just east of the Montana line, 2,921 heat units, during their respective frost-free periods. A comparison of these figures with those in the table indicates that the temperature conditions in Montana are not suited to the production of the large type of corn grown in the Central West. Montana farmers will do well to confine their corn-growing efforts to the more rapidly growing strains, as the

Northwestern corn belt differs substantially from that of the Central West.

HOURS OF SUNSHINE

Robinson* states that the greater duration of summer sunshine

TABLE II. SHOWING THE DATES OF THE LAST SPRING AND THE FIRST FALL FROSTS AND THE AVERAGE NUMBER OF HEAT UNITS DURING THIS PERIOD AT VARIOUS POINTS IN MONTANA FOR AN AVERAGE OF TEN YEARS, ENDING WITH 1912.

Town	County	Date of last sprng irost	Date of first spring frost	Number of days frost-free	Number of heat units for frost-free period
Miles City	Custer	May 7	Sept. 30	146	3,971
Forsyth	Rosebud	" 22	" 23	124	3,496
Crow Agency	Big Horn	" 16	" 24	131	3,336
Glendive	Dawson	" 20	" 18	121	3,319
Great Falls	Cascade	" 6	" 25	142	3,163
Ekalaka	Custer	" 26	" 26	123	3,156
Fort Benton	Chouteau	" 12	" 25	136	3,030
Billings	Yellowstone	" 19	" 15	119	2,979
Missoula	Missoula	" 15	" 25	133	2,878
Helena	Lewis and Clark	" 6	" 30	147	2,872
Havre	Hill	" 13	" 14	124	2,863
Chinook	Blaine	" 15	" 12	120	2,851
Hamilton	Ravalli	" 15	" 20	128	2,844
Kalispell	Flathead	" 5	" 30	148	2,624
Plains	Sanders	" 25	" 16	114	2,496
Lewistown	Fergus	" 24	" 6	105	2,152
Dillon	Beaverhead	" 26	" 3	100	2,092
Virginia City	Madison	" 30	" 6	99	2,053
Bozeman	Gallatin	June 2	" 6	96	1,961
Anaconda	Deer Lodge	" 2	" 2	92	1,788

* Lit. cit., p. 176.

in high latitudes forces vegetation at an extraordinary rate. He points out that "during the three summer months, the sun is above the horizon 1,403.8 hours at Crookston and 1,373.5 at St. Paul, against 1,355 at Milwaukee and 1,337.2 at Peoria, in the heart of the Illinois corn country." Studies of the weather records show that the actual number of hours of sunshine is relatively greater in northern latitudes than is the theoretical, when compared with points to the south. In Montana light precipitation which means much cloudless weather favors the rapid growth of vegetation.

MOISTURE REQUIREMENTS

In tests reported by Briggs and Shantz* and in a summary by these authors of work so far conducted, it is shown that the amount of water required to produce a pound of dry matter in corn ranged from 275 to 370 pounds, while with small grains—wheat, barley, oats, and rye—the requirement was from 510 to 700 pounds, and with alfalfa, sweet clover, and Canada peas the amount of water required to produce a pound of dry matter ranged from 770 to 1,070 pounds.

This light moisture demand is of highest importance to the dry farmer since moisture supply is the limiting essential in the crop-producing possibilities of a dry farm region; crops like corn with low moisture requirements must ultimately take an important place on dry farms.

HAIL RESISTANCE

It has been the general observation that corn is injured by hail as little as almost any crop that the Montana farmer may grow. With wheat or other small grains, hail injury is very serious but with corn the loss is usually comparatively slight. The farmer who grows a field of corn in most sections of Montana is almost certain to have a fodder return even if temperature and storm conditions are very unfavorable.

VARIETIES BECOME ACCLIMATED TO A LOCALITY

The chief end of plants is to reproduce themselves and if a particular kind survives in a locality it must perform this function under

* The Water Requirements of Plants. U. S. Dept. Agr., Bur. Plant Indus. Bul. 285.

the conditions there existing. The stem and leaves are for the purpose of transporting and assimilating food and these must develop to a certain point before the seed can be produced. A plant like corn, which is very plastic, adapts itself to the moisture, soil, and temperature conditions where it may be growing. In a locality with a long frost-free period, when all the ears in an early variety that may be introduced will ripen, the tendency will be to select the largest, which will usually be the latest ripening, ears for seed. These will

FIG. 28. a, Hill of Lansing corn. This variety has been grown on bench land near Miles City for twenty-five years and shows a type of dent stalk adapted to eastern Montana dry lands. b, Funk's Ninety-Day, typical of the more southern types of corn. Tall, coarse stalk.

normally be from plants with large stem and leaf development, and the effect will be to develop larger leaves and stems and bigger ears. The variety will become adjusted to the longer season, or acclimated to the locality. After a long period of growth the variety will become very definitely adjusted to the section of country and will be specially suited to growth there.

In contrast with the ability to lengthen the growing season, we find that corn can be adjusted to shorter seasons of growth. When a variety is first changed to a condition where the frost-free period is shorter than where it was previously grown, provided the change is not too great, the effect will be for the later plants to be injured by frost and for only the very earliest to mature. The tendency here will be to choose ears for seed from the earliest plants, and the variety will become adjusted or acclimated to the new condition. The stems will be smaller, the leaf development will be reduced, and the ears will not be so large as formerly. After a number of years in the shorter season the variety becomes very definitely adapted to the conditions and may be grown with safety.

SAME SIZE TASSELED OUT AS WHEN RIPE
BUT NOTE DIFFERENCE IN FOOD VALUE

FIG. 29. Diagram showing importance of growing mature corn. (Courtesy North Dakota Experiment Station.)

ACCLIMATED VARIETIES IMPORTANT IN MONTANA

Through the many years of cultivation and selection by the early Indians as well as by growers of more recent times, corn varieties

have been developed that are well suited for growth under Montana conditions. In varieties like the Dakota White Flint, Gehu Flint, Northwestern Dent, Rustler's White Dent, and others, we find the characteristics that make for early corn. The stalks are small and comparatively short, the lower internodes are short, and there is abundant growth of early leaves from the lower part of the stem.

Part V. Agronomic

EXPERIMENTS WITH CORN

The purpose of these experiments was to study the characteristics which differentiate the groups of northern corn as described in this bulletin from the types of the corn belt. These characteristics are described under the following headings, namely, the leaf area, the suckers, the stalk, characteristics and style of ear, and the shelling percentage. The results given are based on data secured during the years 1913 and 1914.

It perhaps may be contended that the work is based upon too short a time for reliable data, yet it is not likely that more extended observations would change the relative proportions between the different groups, as such characteristics are inherent within the group itself and would not vary greatly except under decidedly abnormal environment. A large number of northern varieties of corn were tested and the results are given. Because of lack of time and funds a comparison of results with the leading varieties of the corn belt has not yet been made.

This study of types and varieties of corn was undertaken at Wibaux, in the extreme eastern part of the State. This point was selected because it represented the conditions of eastern Montana fairly well. It is about midway between the Yellowstone River and the divide at the head of Beaver Creek and represents neither the most favorable conditions with maximum heat units, such as would be found in the Yellowstone bottoms, nor the cold nights with lower heat units that would be characteristic of the high divides at the source of the creeks tributary to the Yellowstone or of the south Missouri watershed. The soil of the experiment plots was a sandy loam. The altitude is 2,674 feet.

LEAF AREA AND SUCKERS OF CORN

Northern corns are greatly given to producing suckers or tillers. By way of illustration the following data on suckers produced at Wibaux in 1913 are interesting: In the early flint group 73.7 per cent of the plants produced suckers; in the late flint, 71.5 per cent;

in the semident, 31.6 per cent; in the early dent, 39.4 per cent; and in the late dent, 22.8 per cent.

This corn was planted in checks of 3 feet 6 inches and thinned, when two inches high, to three stalks per hill. Lyon* has pointed out a number of factors which affect the production of tillers. He names principally thickness of stand, type of planting, and character of season, and shows that the number of tillers varies as these factors vary. Common observations agree that the flints and sweet corns are yearly given to producing tillers, and the same is true to a certain extent of the northern types of dent.

Montgomery** makes the following statement concerning the origin of tillers:

"From a botanist's point of view a tiller is simply a lateral branch, arising from one of the lower nodes. The corn plant, like other members of the grass family, has a tendency to develop branches near the ground. In fact, the early progenitor of the corn plant (sometimes thought to be *teosinte*) was undoubtedly a much branched plant, the branches being almost as large as the primary plant. Rudimentary branches can yet be seen in any young corn plant, and under certain conditions will develop, when they are called 'tillers.'

"The branches from the upper or middle nodes, however, have become only ear bearing, so that these are now really rudimentary ears, while the branches in the lower nodes are still true branches, similar to the main plant.

"While a single plant, no doubt, at one time, produced a large number of branches and small ears, they have been reduced to their present number largely through artificial selection. Man would naturally choose the larger ears for seed, and these would grow on the plants producing the fewest number. Hence, any present development of these branches may be regarded as more or less atavistic, and will be influenced by the environment of the plant.

. . . . . .

"While the bearing branches have been reduced to one or two, the lower branches have also been reduced in number; in fact, they have been so far subordinated in some of the higher types of corn that their general development as tillers is looked upon more as the exception than as the rule."

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* Lyon, T. L. Experiments with Corn. Nebraska Exp. Sta. Bul. 91.

** Montgomery, E. G. Tillering of the Corn Plant. Nebraska Academy of Sciences.

FIG. 30. How basal tillers and ear shoots are borne on early flint corns.

FIG. 30. How basal tillers and ear shoots are borne on early flint corns.

Numerous experiments in removing tillers or suckers have been made, most of which have resulted in a decided decrease in the yield of the corn that was thus treated. A limited test in Nebraska showed a difference of seventeen bushels per acre in favor of the untreated corn.* In his paper on tillering in corn, Montgomery concludes that "just what the economic value of tillers is, has not yet been fully established but the popular cry against them at present is not warranted."

Inasmuch as the plant food is largely elaborated through the leaves, it is natural to suppose that the area of the leaf surface bears a relation to the capacity of a corn plant to produce grain. The physiological functions of the leaf are performed through the stomata, which are small, pore-like openings on both the upper and lower leaf surfaces. Through these is transpired the water which has been used in plant growth. The interchange of gases also takes place through the stomata. It is estimated** that in the corn leaf there are about 60,630 stomata per square inch on the upper surface and 101,910 per square inch on the lower side of the leaf.

Plant physiologists regard the rate of transpiration as one of the more definite measures of plant growth. Transpiration depends to a certain extent on the leaf surface or the stomata. Duggar*** says, "It has long been evident that there is, under certain circumstances, a relation or fairly definite ratio between transpiration and growth. . . . It is observed, then, that transpiration and relative growth vary with weight and area of the leaves."

In discussing the corn leaf, Burtt-Davy† says, "The importance of the leaf in the life-history of the plant is thus evident; *it is a chemical laboratory in which the various elements of plant-food are separated out from the compounds in which they originally occur, and are re-united into such forms as can be made use of by the plant.* Maize plants poor in leaf-surface, through lack of food or water, or from insect-injury, damage by hail, or undue shortness

* Nebraska Exp. Sta. Bul. 91.

** Montgomery, E. G. The Corn Crops, p. 35. New York, The Macmillan Co., 1913. See also Duggar, B. M. Plant Physiology, p. 93. New York, The Macmillan Co., 1911.

*** Lit. cit., p. 102.

† Lit. cit., p. 83.

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FIG. 31. Diagram of corn plant showing function of roots, stem, and leaves.

of growing season, cannot manufacture and store as much starch, and therefore fail to develop as much weight of grain as those with a proper proportion of leaf. It does not necessarily follow, however, that the larger the leaf-surface the greater the amount of seed produced. *Beyond a certain point* (which perhaps varies in different varieties or breeds), the amount of seed produced appears to decrease in inverse ratio to the increase in leaf-surface."

With the shedding of the pollen the stalk ceases to elongate and there is practically no further leaf development save that of suckers and ear leaves. There is an intimate relationship, therefore, between the time needed to produce the leaf system and that required to effect the maturity of the grain. It is logical to presume that in the process of adaptation each type of corn has within reasonable limits adjusted the size of the ear to its leaf area. In the evolution of corn those plants which grew in warm regions developed a tall primary branch or stalk which would act as a scaffold for the growth of leaves, thus compensating for the leaf area lost through the decrease in the other branches that were tending to become rudimentary. Much evidence tends to show that the common dent corns of the corn belt, which produce tall stalks and few tillers, were developed in regions of relatively high heat units.

On the other hand, the fact that the flints and sweet corn are now the earliest corns and will produce ripe grain in regions of high altitude, short seasons, and low heat units (where dents will not begin to mature), would indicate that they have grown largely under these adverse conditions. In presenting evidence to support his theory that corn originated in the high plateau region of Mexico, Harshberger* says, "The branching habit, the reproduction of the plant by suckers, the small size of the grain, clearly indicate a very primitive condition of the plant." Now, by the same line of reasoning that we presume corn under conditions of high heat units evolved the tall main branch with the attendant large leaf surface, maintained by the increase of nodes and leaves, we may also presume that in regions of low heat units, this development of one branch into a main stalk would result in a great decrease of the leaf area, for the length of the season would not permit the growth of a stalk with

* Maize: A Botanical and Economic Study, p. 94.

numerous nodes and leaves. Therefore the capacity of the plant to produce grain would be very small since the leaf area was so greatly diminished. By the same line of reasoning may we not assume that in the evolutionary development of the flints, the early group especially, the rudimentary branches have been retained, not for the purpose of each producing a small ear as formerly, but to supply the leaf surface requisite during a short season. In apparent contradiction to this statement might be cited the Pueblo Indian maize

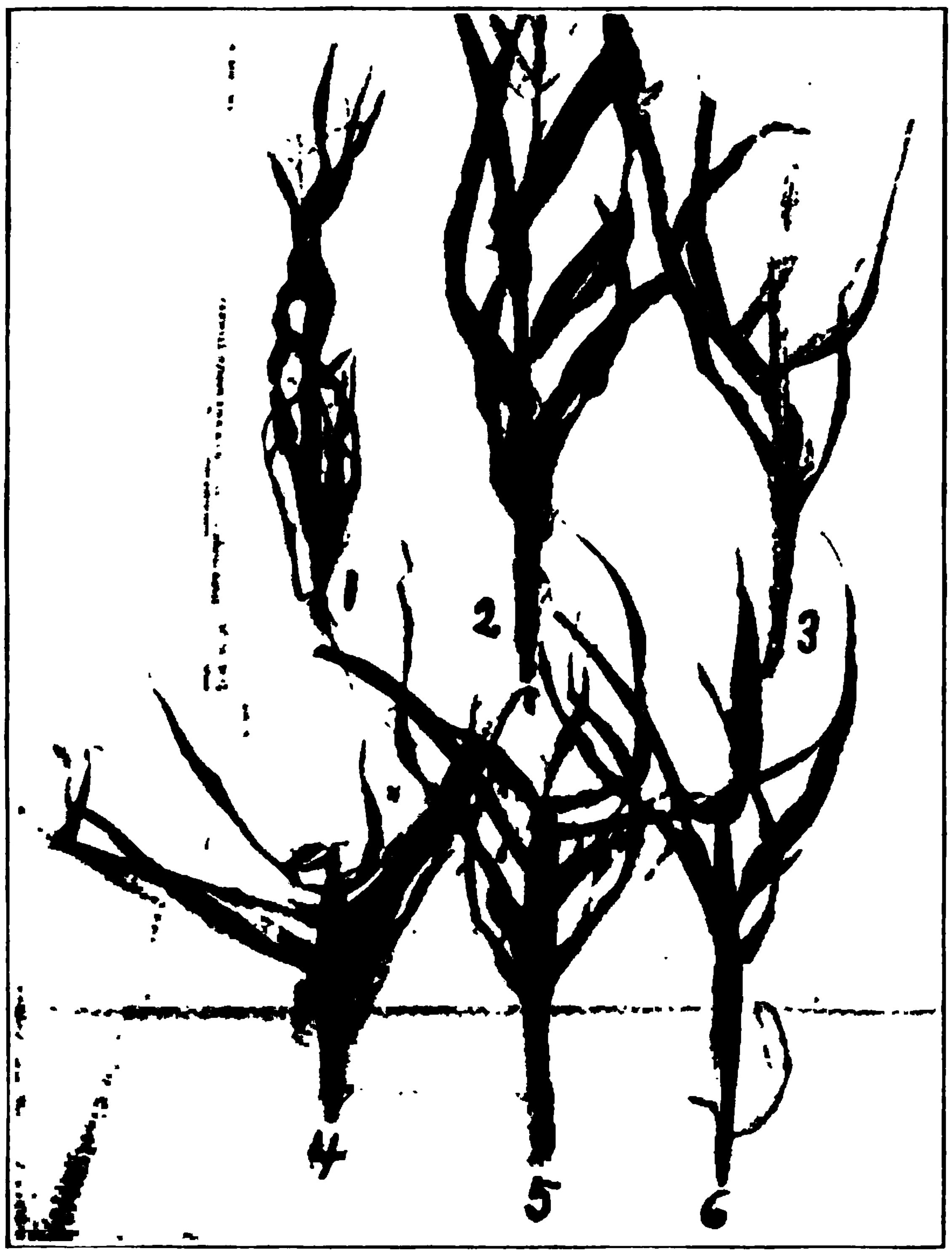

FIG. 32. Types of suckers or tillers and ear shoots from early flint corns. 1, Basal sucker with roots, tassel, and one ear shoot; 2, basal sucker, no roots or ear shoot; 3, basal sucker, no roots or tassel but small nubbin; 4, leafy ear shoot with fairly well developed ear; 5, leafy ear shoot, unfertilized cob; 6, leafy ear shoot, almost no cob development.

described by Collins:* "However, this corn has been grown in almost a desert region, even though it be one of extremely high heat units. Moisture is the limiting factor and likely the peculiar adaptation is a result of this rather than of temperature." The authors are of the opinion that the adaptation in the corn of the upper Missouri Indians is just as wonderful if not as striking as that of the Pueblo Indian corn.

In order to secure data upon this matter, a study was made of the surface of the leaves and number and length of internodes of the stems of a number of typical varieties of corn in each group. Late in August, 1914, measurements of height from the first node to the base of the tassel and counts of the number of leaves and suckers were made of one hundred plants of each variety. From this study an average individual plant was selected and the area of each leaf on the main stalk, suckers and ears was determined by the method of Ganong.**

Because of the character of its grass-like ancestors, the corn plant produces buds at each node of the main branch. In the dent corns, with the exception of the bud which develops into the main ear, these are more or less abortive and aside from those on the lower nodes rarely develop enough to show above the leaf sheath. Sometimes they develop into abortive ears, or rather into a mass of husks inclosing a small, undeveloped cob. Occasionally on the lower nodes these develop into suckers or tillers. Therefore all the ears and suckers are essentially the development of the lateral buds of the main stem.

Usually one and frequently two suckers in the flint groups spring from the base of the main stalk; these are termed basal suckers. Those which spring from the nodes are designated by the node from which they sprang, beginning with that nearest the base of the plant.

Students of the evolution of corn agree that the ear is the development of the central spike of what was at one time a part of a branched spikelet, similar to the tassel, and that the ear shank is homologous to the stem, and the husks to the leaf sheath to which

* Pueblo Indian Maize Breeding. In Journal of Heredity, vol. 5, p. 255. 1914.

** Ganong, Wm. F. Plant Physiology, p. 177. New York, Henry Holt, & Co., 1908.

the leaf is attached.* In dent corns small abortive leaves frequently are produced on the ends of the husks, but in the early flints these leaves are often the size of leaves produced half way up the stalk.

Frequently ear-like shoots are produced upon the lower nodes of the early flint stalks below the main ear. Under favorable conditions these develop all the way from small nubbins or cobs with a few scattering kernels to almost perfect ears of considerable size. With unfavorable conditions, however, the cob is abortive but the husks produce an abundance of ear leaves.**

As can be noted in photographs of typical early flint plants shown in this bulletin, they produce a mass of leaves close to the ground. Many of these leaves come from suckers and ears.

FIG. 33. Suckers and ear shoots from single plant of early flint corn. 1 and 4, Ear shoots borne at first and second nodes; 2 and 3, basal suckers or tillers; 5, main ear, borne on the third node. These ear leaves are borne on the husks of ears of northern corns, especially the early flints. They show the effort of the plant to maintain a large leaf surface without a large stalk.

* Burtt-Davy, Joseph. Lit. cit., p. 80.

** Montgomery, E. G. What is an Ear of Corn? In Popular Science Monthly, Jan., 1906. Perfect Flowers in Maize. Ibid. Oct., 1911.

From Table III it will be noted that in the case of the early flints the leaf area of the main stalk is very small in comparison with that of any varieties of the other groups, being 247.7 square inches in the case of Dakota White and 342.7 in the Gehu; while in Rustler it is 554.4 square inches; Minnesota 23, 545.5; Funk's Ninety-Day, 1,050.8; and large corn from Yuma, Arizona, 2,339. This last variety had not yet produced a tassel, so that the total area would have been still greater. However, the total area, including sucker and ear leaves, for the early flints is greater than that of any of the other groups with the exception of the southern corns. The Disco Squaw, which has a large leaf area of 1,416.3 square inches, is one of the largest of the early flint group. The seed of this corn came from north central South Dakota, and that of the Gehu, Dakota White, and Burleigh County from Bismarck, North Dakota. It is a significant fact that of the corns adapted to this State, the early flints have not only the largest leaf surface but so far have been the heaviest yielders upon dry land in Montana.

The reader is cautioned that the averages shown in the table of leaf area are not designed for comparison across groups, since the number of individual plants studied does not remain constant. The table shows, however, the leading facts regarding the distribution of surface over stalks, suckers, and ear leaves in the several classes. Since the Funk's Ninety-Day had not developed so far as the other corn, the facts obtained should not be used in comparing it with plants of the same sort grown in Illinois. The group averages indicate that early flint corns have 10 per cent less leaf area than Funk's Ninety-Day, though the latter is about twice as tall; but they have substantially 50 per cent more area than the semident or early dent group. All of this increased area comes from the ear leaves and suckers. Readers should note the proportions in the yield for these groups as averaged for the two seasons in Table III.

STALK CHARACTERISTICS OF NORTHERN CORN

The stems of the same plants that were used in the leaf-area determinations were used for a study of the number of nodes and the length of internodes. If the theory of the development of the early flint group as outlined in the discussion of tillers be true, we

TABLE III. SHOWING LEAF AREA† IN SQUARE INCHES OF CORN GROWN AT WIBAUX IN 1914

Variety	Main stalk	Suckers				Ear leaves				Total for one side	Total leaf area
		Basal node	First node	Second node	Third node	First	Second	Third	Fourth		
Early Flint											
Dakota White	247.7	102.2	156.9	....	....	47.5	148.3	....	....	702.6	1405.2
Gehu	342.7	56.6	135.1	162.4	....	57.6	45.5	20.	....	819.9	1639.8
Burleigh County	317.2	222.1	89.1	139.5	209.1	64.2	....	....	208.7	1249.8	2499.6
Disco Squaw	536.3	208.2	305.	....	....	131.2	116.5	80.4	38.7	1416.3	2832.6
Bolley	289.7	53.4	100.1	....	....	100.1	124.7	158.	....	826.	1652.
Beal	348.6	156.4	116.8	139.5	....	....	....	....	....	761.3	1522.6
Rea	434.6	46.5	127.6	....	....	76.	46.2	8.9	24.1	763.9	1527.8
Average	359.3	....	....	....	....	....	....	....	....	934.3	1868.6
Late Flint											
Longfellow *	886.6	....	....	....	....	120.5	86.3	105.3	....	1198.7	2397.4
King Philip	546.9	228.1	150.6	....	....	....	....	....	....	925.6	1851.2
Average	716.8	....	....	....	....	....	....	....	....	1062.2	2124.4
Semident											
Minnesota King	674.2	....	....	....	....	....	....	....	....	674.2	1348.4
Minnesota 23	545.5	....	....	....	....	7.2	7.2	....	....	559.9	1119.8
Northwestern Dent	472.8	39.9	....	....	....	58.5	11.1	....	....	582.3	1164.6
Average	564.2	....	....	....	....	....	....	....	....	605.5	1211.
Early Dent											
Early Pride	545.5	....	....	....	....	....	....	....	....	545.5	1091.
Lansing	544.	....	....	....	....	....	....	....	....	544.	1088.
Sioux Chief	468.4	....	....	....	....	....	....	....	....	468.4	936.8
Rustler's White Dent	554.4	....	....	....	....	....	....	....	....	554.4	1108.8
Minnesota 13**	460.1	....	....	....	....	....	....	....	....	460.1	920.2
Minnesota 13***	823.5	....	....	....	....	57.2	57.2	....	....	937.9	1875.8
Robertson	407.8	....	....	....	....	....	....	....	....	407.8	815.6
Average	543.4	....	....	....	....	....	....	....	....	559.7	1119.4
Late Dent											
Funk's Ninety-Day	1050.8	....	....	....	....	....	....	....	....	1050.8	2101.6
Yuma, Arizona	2339.1	....	....	....	....	....	....	....	....	2339.1	4678.2

† Unless otherwise noted, the data in this table are based on one surface of the leaf. Since both the upper and lower sides function, the total leaf area includes both sides.

* This variety suckers considerably, though the stalk selected was free from suckers.

** The seed of this corn was grown by Mr. E. Elker near Huntley in Yellowstone County.

*** Seed grown in central Minnesota.

Note.—Mr. L. C. Burnett, of the Iowa Experiment Station, has kindly furnished us the following data based upon a study of fifty typical stalks of Reid's Yellow Dent, grown at Ames, Iowa, in 1915:

Average height of stalks .... 9.76 feet
Average number of leaves per stalk 14.17
Average leaf area per stalk (one side) .... 1310.76 square inches
Total leaf area per stalk (both sides) .... 2621.52 square inches

TABLE IV. SHOWING LENGTH OF STALK IN DETAIL. (Corn grown at Wibaux in 1914.)

Variety	First inter-node (inches)	Second inter-node (inches)	Third inter-node (inches)	Fourth inter-node (inches)	Fifth inter-node (inches)	Sixth inter-node (inches)	Seventh inter-node (inches)	Eighth inter-node (inches)	Ninth inter-node (inches)	Tenth inter-node (inches)	Eleventh inter-node (inches)	Twelfth inter-node (inches)	To base of tassel (inches)	Tassel (inches)	Total length of stalk (inches)
Early Flint															
Dakota White	1.	2.25	3.25	4.5	4.75	5.25	....	....	....	....	....	....	7.5	8.	36.5
Gehu	2	3.25	4.	3.75	3.5	3.75	4.	....	....	....	....	....	7.	11.	42.25
Burleigh County ...	2	3.	4.	3.5	3.25	3.25	4.	....	....	....	....	....	8.	12.	43.
Disco Squaw	1.5	3.25	4.	4.	4.	4.	3.75	4.5	4.5	....	....	....	9.	10.	52.5
Bolley	2.	2.75	3.25	3.5	3.75	5.	6.	6.75	....	....	....	....	9.	12.	54.
Beal	1.5	2.	2.	2.	4.5	6.	7.	....	....	....	....	....	9.	14.	48.
Rea	1.	2.	3.	3.5	5.5	7.	7.	....	....	....	....	....	12.	16.	57.
Average.........	1.6	2.6	3.4	3.5	4.2	4.9	5.4	5.6	4.5	....	....	....	8.8	11.9	47.6
Late Flint															
Longfellow*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
King Philip	2.5	3.75	4.75	5.	5.	7.5	7.5	6.5	6.5	....	....	....	....	17.	66.
Semident															
Minnesota King	1.5	3.	3.75	4.75	5.5	7.	3.75	6.	5.25	5.	4.5	....	7.5	16.	73.5
Minnesota 23	2.	3.75	4.	5.5	6.	6.	5.	5.	5.5	....	....	....	9.	17.	68.75
Northwestern Dent .	1.	2.5	3.75	6.	7.	5.25	5.25	6.	....	....	....	....	9.	22.5	68.25
Average.........	1.5	3.1	3.8	5.4	6.2	5.7	4.7	5.8	....	....	....	....	8.5	18.5	70.1
Early Dent															
Early Pride	2.25	3.5	5.5	6.5	6.	6.	6.	5.5	4.75	....	....	....	9.	15.	70.
Lansing	2.	3.	5.	6.	5.5	6.5	6.	4.75	....	....	....	....	6.	14.	58.75
Sioux Chief	2.5	3.5	4.5	5.25	5.	4.75	4.75	....	....	....	....	....	4.5	15.	49.75
Rustler	2.	3.	2.75	3.5	6.	6.5	5.5	5.5	5.	5.	....	....	12.	12.	68.75
Minnesota 13**	3.	4.5	6.	7.5	6.5	7.	6.	5.5	....	....	....	....	9.5	14.	69.5
Minnesota 13***	1.5	2.75	3.75	4.75	4.75	4.75	4.5	5.5	6.5	6.5	....	....	7.	16.5	68.75
Robertson	1.5	2.75	4.5	5.25	5.5	4.	4.	3.5	....	....	....	....	8.	14.	53.
Average.........	2.1	3.3	4.6	5.5	5.6	5.6	5.25	4.3	5.4	5.8	....	....	8.	14.5	62.6
Late Dent															
Funk's Ninety-Day .	2.75	4.	5.5	7.75	8.	7.	6.	5.	4.	3.	3.	2.	7.	17.	82.
Yuma, Arizona	2.75	4.	5.	5.5	4.	3.	3.	3.	3.	3.	3.	3.	....	....	†84.

* No notes on length of internodes. ** Seed grown in Yellowstone County. *** Seed grown in central Minnesota. † This corn grew to the sixteenth internode without tasseling and was 84 inches high when the data were gathered.

would expect this group to produce short, fine stalks, with relatively few nodes and short internodes.

Table IV shows that there is not a great variation in the lengths of the first, second, and third internodes of any of the groups. After that the other groups begin to lengthen out when compared with the early flints. The stalks of the early flints have from six to nine internodes, the semident eight to eleven, the early dent nine to ten, while Funk's Ninety-Day—an early Illinois corn—had twelve. Therefore the stalks of the early flint group are not only much shorter but have decidedly fewer internodes than other groups of corn.

The data presented by the leaf studies and stalk studies seem to indicate that in the economy of nature the early flint corns had adapted themselves to regions of shorter seasons and low heat units by preserving the basal shoots of the prehistoric progenitor of corn, and through these and the ear shoots and the ear leaves were enabled to secure the leaf area for elaborating food that the southern dent corns gained by the extension of the main branch by the addition of nodes.

HEIGHT OF EAR ON STALK OF NORTHERN CORN

Another characteristic of the northern corns as compared with those of the corn belt is that the ears are produced on lower nodes and consequently close to the ground. It is hard for some who have been accustomed to ears from "waist to shoulder height" in the corn states to understand how corn of value can be only knee high from the ground. Table V gives about the average node from which the ear has developed and the average height from the ground. This is one of the factors which necessitate a harvesting method different from husking in the field from the standing stalk.

SIZE OF EARS OF NORTHERN CORN

It is not to be expected that corns growing in a region of relatively low heat units can produce ears the size of the standard corn belt varieties, even though the leaf area is comparatively high. Ears of corn which in size come up to the Iowa standards are sometimes exhibited at fairs in this State but they are exceptional and are often misleading. The tendency of all the varieties which

have established a reputation for maturing in this State is to produce short ears. This is especially true of the early dents. A study was made of the length of ears as they run in the field. Before the produce from the plots in the variety tests was shelled in the spring to determine the shelling percentage, the ears were sorted according to length. Table V gives the results of this study for the leading varieties.

The relatively high percentage of small ears will be noted. Ears

FIG. 34. Showing the position of ears on different types of stalks. 1 and 2, Northwestern Dent; 3 and 4, Dakota White Flint. The figures indicate the nodes.

TABLE V. SHOWING LENGTH OF EARS AND THEIR LOCATION ON THE STALK.
Corn grown at Wibaux. Average for 1913 and 1914.

Variety	Percentage of ears of different lengths								Percentage of shelled corn to whole ear	Height of ear from ground	Node to which main ear is attached
	4 inches or less	4 to 5 inches	5 to 6 inches	6 to 7 inches	7 to 8 inches	8 to 9 inches	9 to 10 inches	10 to 11 inches			
Early Flint											
Dakota White	14.5	15.	21.4	18.4	24.9	6.8	....	....	76.9	9	Fourth
Gehu	34.1	17.	18.9	14.9	13.1	3.8	....	....	77.5	10	Third
Burleigh County	7.3	14.8	13.6	17.2	23.3	18.8	5.	....	84.5	10	Third
Late Flint											
Smut Nose	17.	15.5	13.4	16.8	24.2	11.8	1.3	....	64.2	20	....
King Philip	13.3	10.4	15.8	18.	22.3	7.2	13.	....	68.4	18	Fourth
Triumph	14.	10.	12.	23.	13.	14.	12.	2	77.2	22	....
Longfellow	13.3	7.6	20.6	22.7	20.7	12.5	2.7	....	70.2	22	....
Mercer	15.8	11.8	17.	18.6	20.	14.8	2.	....	68.2	21	....
Semident											
Minnesota 23	28.7	19.8	31.7	15.4	3.9	.5	....	....	77.2	22	Fourth
Northwestern Dent	32.	18.	23.	15.2	9.8	2.	....	....	76.8	20	Fourth
Minnesota King	11.	9.8	24.8	32.	19.4	3.	....	....	67.6	24	Seventh
Early Dent											
Rustler	38.9	25.5	20.8	11.8	3.	....	....	....	78.	17	Sixth
Brown County Dent	38.4	24.8	24.4	10.	2.4	....	....	....	79.7	22	Fourth
Minnesota 13	31.6	29.	24.6	13.8	1.	....	....	....	80.	24	Fourth
Square Deal	38.5	30.5	21.	10.	....	....	....	....	72.6	18	....
Pioneer White Dent*	21.8	23.8	36.	14.8	2.8	.4	....	....	68.7	20	....
Late Dent											
Pride of the North	28.	31.	23.	16.	2.	....	....	....	75.2	28	....
Sterling White Dent*	18.1	26.8	7.8	26.	13.3	7.8	....	....	73.7	....	....
Sterling White Dent*	18.1	26.8	7.8	26.	13.3	7.8	....	....	73.7	....	....

* No ear data for 1913.

In connection with the percentage of corn to ear, it should be stated that the low percentage in both the late dents and flints was due to immaturity of the kernels, there being a large percentage of immature ears in both.

of this size are difficult to husk by hand, hence another demand for a different harvesting system from that commonly used in the corn states.

SHELLING PERCENTAGES OF NORTHERN CORNS

The percentage of shelled corn to the cob depends largely upon the depth and shape of the kernel and the filling at the tip and butt. These are factors that can be controlled and intensified to a certain degree by breeding. As yet but little breeding has been done with the northern corns. Minnesota 23 and Minnesota 13 are notable exceptions. The really important point, however, is the number of pounds of shelled corn of good quality and not the percentage of corn to the cob, which should be incidental to the yield. The produce of the plots in the variety tests at Wibaux was stored in bags in a dry, warm basement until shrinkage ceased and a constant weight was reached. It was then shelled and the percentage of shelled corn determined.

Table VI shows that the three adapted groups—the early flint, early dent, and semident—have about the same shelling percentage, which varies from 70 to 80 per cent. The standards for show corn in the corn belt are from 85 to 87 per cent. In studying the table of shelling percentage, the reader should bear in mind that these data are based upon the entire crop and not selected show ears.

PLANT PROPORTIONS OF NORTHERN CORNS

The plants selected in 1914 for leaf-area study were carefully preserved. They were placed in cheesecloth bags and thoroughly dried. Later they were divided into coarse stalk (that part which stock would not eat), fine leaves, stalks and husks, cob, and shelled corn. The relatively low percentage of coarse stalks is an index of good feeding value. The northern corns are decidedly lower in the percentage of coarse material than the tall, coarse corns of the Middle West. This is important not only because of the feeding value but because of the ease with which they may be threshed. The high proportion of shelled corn to the total weight of the plant should also be noted in the case of the early flints. The high proportion of fine leaf and stalk in the late flint group should be

TABLE VI. SHOWING PROPORTIONS OF COARSE AND FINE STALK, SHELLED CORN, AND COB, IN MONTANA TYPE OF CORN. AIR-DRY WEIGHTS. (GROWN AT WIBAUX IN 1914)

Variety	Coarse stalk (per cent)	Fine stalk, leaf and ear shucks (per cent)	Shelled corn (per cent)	Cob (per cent)
Early Flint				
Dakota White	4.6	32.1	48.1	15.2
Gehu	14.	41.8	34.	10.2
Burleigh County Mixed	8.6	35.5	40.5	15.4
Disco Squaw	8.8	30.9	47.3	13.
Bolley	5.3	32.	49.6	13.1
Beal	....	47.7	37.3	15.
Rea	14.7	36.4	37.9	11.
Average	9.3	36.6	42.1	13.3
Late Flint				
Longfellow	11.9	48.	31.4	8.7
King Philip	16.	43.	30.4	10.6
Average	13.9	45.	30.9	9.6
Semident				
Minnesota King	19.2	38.6	32.9	9.3
Minnesota 23	21.7	41.7	26.5	10.1
Northwestern Dent	14.5	35.9	35.4	14.2
Average	18.5	38.7	31.6	11.2
Early Dent				
Early Pride	15.7	34.7	37.7	11.9
Lansing	17.4	40.3	32.2	10.1
Rustler's White Dent	13.	44.9	31.9	10.2
Minnesota 13*	16.9	33.6	42.6	6.9
Minnesota 13**	22.	40.4	27.5	10.1
Robertson	15.	33.8	43.9	7.3
Average	16.7	38.	36.	9.4
Late Dent				
Funk's Ninety-Day	36.8	53.1	8.2	1.9

* Seed grown in Yellowstone County.

** The seed for this was grown in central Minnesota.

noted. In the light of the data available at the present time and the experience of farmers, the corns of this group are better adapted to fodder production than to grain.

FIG. 35. Product of three kernels of Dakota White Flint. Weight of stover, 400 grams; grain, 695 grams. A perfect stand of hills like this would have yielded 76 bushels to the acre.

HARVESTING MONTANA CORN

Because of the peculiar stalk and leaf characteristics of Montana corn, together with the small sized ear, the methods of harvesting will have to be different from those followed in the Central states. The nature of the crop as grown in Montana and the practices so far followed by growers, point to two methods which have proved practicable. These are the harvesting of the crop, especially the early flints, in the field by feeding off with sheep or hogs, and cutting the crop with the corn binder for silage, threshing or bundle feeding. These methods are fully discussed in Circular 41 of the Experiment Station and will not be dealt with in this bulletin. However, the recognition of the fact that harvesting methods peculiar to northwestern corns will have to be adopted by Montana farmers is of importance in the development of corn-growing on Montana farms.

TESTS OF CORN VARIETIES

This bulletin was not prepared with the object of giving results of variety tests. It deals with the climatic environment in Montana as related to corn growing and the characteristics and history of the types of corn that are adaptable to this environment. Thus the limited data on yields of varieties are not given by any means as final. Variety tests to be of value must cover a period of years in conjunction with liberal replication and check plots. Even under the best conditions with small plots the experimental error is apt to be great, and the results only apply to regions where conditions are similar to those under which the test has been made. The tables of yields herein included are given simply as a report of progress and should be interpreted only in connection with the environmental conditions of heat units and moisture which prevailed that year.

When the corn crop in this State approached the foothills of the Rockies, on lands say of 4,000 feet altitude, its probable limit of practical culture for grain was reached. While undoubtedly the crop will be raised for fodder and as a substitute for fallow at higher altitudes, it is doubtful if any varieties or types will produce grain under conditions of so low heat units as are normal in the intermountain valleys above 4,000 feet. To the east of the foothills described, and in scattering intermountain valleys of low altitude, there are within Montana approximately 18,000,000 acres adapted

to the production in the rotation of crops of some type of corn. This territory does not lie in a level plain as does approximately all of the corn belt of the Middle West. It is more or less broken and cut up by erosion, and frequently there are variations of 500 feet or more in altitude within a few miles. The divide which separates the watersheds of the Yellowstone and the Missouri is said to range from 3,000 to 4,000 feet in altitude, rising with the rest of the country as it nears the mountains. Since it is found in a corn state like Iowa, in which the difference between the maximum and minimum altitude is only a few hundred feet, that varietal corn tests are applicable only to a restricted section, the possibility of the general application of such tests is indeed very limited in a state like Montana, with a variation of three thousand feet in the altitude of her tillable area.

Variety testing of corns in Montana is a difficult problem for the following reasons:

1. Variation in altitude.—Not only does the land gently rise towards the mountains, but the altitude of localities that are near each other varies so greatly that in some places corn has been frosted from two to six weeks before that ten miles away has been "touched."

2. Variation in rainfall.—The rainfall varies greatly, not only from year to year but also during the growing season. Some years in some sections it may be the limiting factor.

3. Variation in heat units.—With sufficient soil moisture the limiting factor in the growth of corn is temperature. As Montana is located on the margin of the corn-growing area, even slight variations in the number of seasonal heat units are of great importance. Certain sections are visited some years by hot, drying winds, and others are subjected to frosts from mountain air currents.

4. Variation in soil.—The soils in Montana's tillable area vary greatly both in texture and composition.

5. Variation in seed and variety standards.—As yet none of the adapted corns are fixed in their type as are the older established varieties of the corn belt. For example, there are known to exist within this State at least ten distinctive types of reddish semident corn, all of which go under the name of Northwestern Dent. It is extremely doubtful if all have a common origin.

Because of this large number of variable factors, farmers are cautioned not to place too much dependence on any particular variety of corn until it has been grown for a number of years in their immediate neighborhood. Instead they are advised to study the types of the northern corns and select varieties for trial rather on type than on the performance of one or two years.

TESTS OF CORN AT WIBAUX

The variety tests started on dry land at Wibaux in 1913 were continued in 1914. The moisture and temperature conditions were close to normal in 1913 and somewhat below normal, especially in length of growing season, in 1914. Incomplete weather data make it impossible to give figures showing perfectly the seasonal conditions for the two years and the normal conditions at this point. From data available, however, it was shown that the last spring frost in 1914 was May 31st and the first fall frost September 3d, giving a frost-free period of ninety-five days. This was considerably below the normal length of the growing season for this section of the State. The precipitation for the two years was nearly normal, while the summer temperature was abnormally high in 1913.

In these tests the varieties have been planted always in duplicate and frequently in triplicate. The corn was checked and cultivated twice each way with medium deep and later shallow cultivation. The plots used were one-fiftieth acre in size. The seed was planted thickly and thinned to a uniform stand of three stalks. A Northwestern Dent of a known source has been used for check plots. When harvested in the fall the produce of the plots was stored in a dry, steam-heated basement where it reached an air-dry state, when it was shelled and the percentage of corn to cob determined. The yields have been calculated on a dry shelled-corn basis, using fifty-six pounds to the bushel. The silage estimate, however, is based on one plot which was cut just prior to frost. Ten per cent was deducted from the green weight of the plot at the time of cutting to determine the silage tonnage. In 1913 thirty-six varieties were grown. Only those were selected which had demonstrated themselves to be of merit in some section of Montana. The seed came chiefly from Montana, North Dakota, and South Dakota, and some from central Minnesota. Early flints and semidents matured well; the most corn

TABLE VII. SHOWING RESULTS OF CORN VARIETY TESTS AT WIBAUX IN 1913

Variety	Mature ears (per cent)	Seed ears (per cent)	Market ears (per cent)	Nubbins (per cent)	Immature ears (per cent)	Barren stalks (per cent)	Stalks bearing suckers (per cent)	Shrinkage after storage (per cent)	Percentage of corn to cob	Height of stalk (inches)	Silage per acre (pounds)	Stover per acre (pounds)	Dry corn per acre (pounds)
Early Flint													
Dakota White Flint	100.	57	30.9	12.1	0	0.	1.	18	76.3	48	14,500	3,200	39.5
Gehu	97.2	35.4	43.4	8.4	2.8	.04	.05	16.1	79.1	48	10,400	2,200	32.8
Burleigh County Mixed	100.	71.7	16.2	12.1	0.	.09	.07	0.6	78.6	48	10,400	2,600	38.7
Late Flint													
Smut Nose	71.7	26.6	40.7	4.4	28.3	.01	100.	23.8	64.3	57	14,500	5,000	19.6
King Philip	74.4	25.7	37.2	11.5	25.6	.04	51.1	12.	64.5	69	14,000	5,000	26.5
Triumph	53.9	8.9	36.7	8.3	46.1	.05	84.3	20.6	63.1	66	17,500	5,000	21.9
Longfellow	50.7	16.4	22.4	11.9	49.3	.01	78.4	16.	62.9	64	17,000	4,500	22.8
Mercer	50.9	11.6	31.9	7.4	49.1	.01	27.6	19.5	64.	60	16,500	4,500	22.9
Semident													
Minnesota 23	100	47.9	37.	15.1	0	.03	43.5	20.	75.2	54	11,000	2,400	24.5
Northwestern Dent	100.	33.9	37.3	28.8	0	.01	35.5	9.	76.5	60	13,000	2,600	33.8
Minnesota King	95.6	33.	35.1	27.5	4.4	.05	31.6	25.1	65.3	66	13,600	4,000	29.5
Early Dent													
Rustler's White Dent	95.5	26.1	47.8	21.6	4.5	.01	61.9	0.	78.7	60	9,000	1,900	31.3
Early Pride	94.3	16.4	49.2	28.7	5.7	.06	45.1	11.	78.	66	10,700	3,200	28.1
Eiker's Yellow Dent	84.	35.2	31.8	17.	16.	1.01	33.8	16	80	66	12,500	3,200	29.5
Square Deal	37.1	2.3	18.2	16.6	62.9	13.	36.9	11.6	70.2	63	12,000	2,800	23.1
Pioneer White Dent	11.	2.	5.	4.	89.	3.3	17.5	28.5	62.5	72	14,000	4,200	26.9
Late Dent													
Pride of the North	41.4	4.6	32.2	4.6	58.6	.5	24.1	22.8	75.4	74	13,000	3,000	20.8
Sterling White Dent	26.9	2.3	20.	4.6	73.1	6.1	13.4	26.	67.5	72	17,600	4,100	23.7

TABLE VIII. SHOWING RESULTS OF CORN VARIETY TESTS AT WIBAUX IN 1914

Variety	Mature ears (per cent)	Seed ears (per cent)	Market ears (per cent)	Nubbins (per cent)	Immature ears (per cent)	Barren stalks (per cent)	Stalks bearing suckers (per cent)	Shrinkage after storage (per cent)	Percentage of corn to cob	Height of stalk (inches)	Silage per acre (pounds)	Dry corn per acre (pounds)
Early Flint												
Dakota White Flint	98.1	76.2	15.8	6.	19.	7.8	35.2	16.6	77.5	47	15,000	27.5
Gehu	95.3	91.1	0.	4.2	4.7	0.	56.2	12.5	76.1	45	16,300	28.4
Burleigh County Mixed	98.8	43.7	43.7	11.4	1.2	3.7	46.5	14.3	90.5	49	14,600	33.9
Late Flint												
Smut Nose	54.3	31.9	15.5	6.9	45.7	22.4	81.	16.6	64.	60	17,600	14.3
King Philip	80.	80.	0.	0.	20.	10.4	74	20.	72.2	61	18,400	23.2
Triumph	76.5	38.3	34.	4.2	23.5	4.8	79.	22.2	71.4	70	18,500	22.3
Longfellow	54.2	54.3	0.	0.	45.7	2.7	71.5	24.3	77.2	66	20,800	27.6
Mercer	79.2	30.3	39.3	9.6	20.8	7.9	68.7	29.9	71.8	68	18,400	20.5
Semident												
Minnesota 23	76.4	47.1	16.2	13.1	23.6	1.8	12.1	17.4	80.2	68	11,300	25.4
Northwestern Dent	100.	17.3	51.	31.7	0.	1.	21.	14.3	47.2	55	17,600	29.
Minnesota King	53.	25.	21.	7.	47.	4.2	20.8	19.	70.	66	16,000	21.4
Early Dent												
Rustler's White Dent	89.2	20.3	54.9	14.	10.8	4.4	3.1	14.2	77.3	54	15,000	29.
Early Pride	92.4	7.4	45.	40.	7.6	5.7	5.7	13.6	81.5	60	15,000	27.7
Eiker's Yellow Dent	91.6	24.2	40.2	27.2	8.4	6.1	12.3	14.6	80.	68	13,000	25.
Square Deal	97.	24.	35.	38.	3.	6.2	7.2	13.5	75.	61	12,000	21.4
Pioneer White Dent	86.2	60.	17.3	8.9	13.8	6.2	7.6	11.1	75.	60	11,500	26.7
Late Dent												
Pride of the North	59.3	31.3	18.7	9.3	40.7	6.2	12.4	21.1	75.	66	14,100	20.5
Sterling White Dent	83.5	22.6	44.	16.9	16.5	9.2	25.4	28.6	80.	72	18,200	25.

was produced by the early flints, the most forage by the late flints.

In 1914 the work was more extended. A systematic search for varieties of corn was made in all the northern states. Corn was secured from Maine, Massachusetts, New Hampshire, Vermont, Rhode Island, New York, Michigan, Wisconsin, Minnesota, North Dakota, South Dakota, Manitoba, Ontario, and Japan. At the time of planting the accession book showed 224 entries. All of these were planted but many were synonyms of standard named sorts. The data given in the 1914 table (No. VIII) are of the same varieties and the same source of seed as reported in the 1913 table (No. VII). The object of this large importation was to secure if possible some strain which would combine heavy yield and extreme earliness. It may be of interest to remark that during that year none of these eastern corns gave as satisfactory results as the varieties that have been developed and grown in North Dakota and South Dakota. The experience of one year, it may be noted in passing, coincides with the findings of Montgomery at the Nebraska station,* that moving corn west has a tendency to make it later in maturing, even though it is moved along the same parallel of latitude. Early corns from northern Maine did not mature with the early flints derived from the Mandan Indians.

* Nebraska Exp. Sta. Bul. 126.

TESTS OF CORN AT HUNTLEY

During the season of 1914 a number of corn varieties were tested at the Huntley Experiment Station, which is located a short distance east of Huntley, in Yellowstone County. The temperature conditions were favorable, the first killing frost occurring October 6th, while the usual date for the first frost is September 19th or 20th. The results of the tests conducted are shown in Table IX.

CORN TESTS OVER THE STATE

In the spring of 1914 sufficient corn to plant one-fiftieth acre each of three varieties was sent to farmers in various parts of Montana. The varieties sent were Northwestern Dent, Dakota White Flint, and Triumph Flint. The corn was sent to those applying for it and fifty cents was charged to cover cost of postage. Corn was furnished to farmers in every county in Montana and it was hoped

TABLE IX. SHOWING THE YIELDS OF THE CORN VARIETIES GROWN AT THE HUNTLEY EXPERIMENT STATION

Variety	Date of maturity	Average weight per bu. on cob	Yield per acre		
			Corn* (bushel)	Stover (pounds)	Total (pounds)
Cassia County Flint	Sept. 21	68.6	58.6	4,161	8,186
Martin's Dent	25	70.6	58.2	4,591	8,708
Triumph	21	74.3	53.8	6,370	10,393
Selection No. 133	28	71.6	50.2	4,928	8,209
Northwestern Dent	15	69.1	50.1	3,720	7,190
Brown County Dent	25	66.6	48.1	3,713	6,919
Longfellow Flint	28	69.6	44.3	2,629	10,717
Minnesota 13	21	69.6	40.5	2,579	5,582
Gehu Flint	5	69.0	37.4	2,471	5,056
Minnesota 23	10	67.0	37.2	2,387	4,778
Fort Peck Squaw	5	69.0	28.4	2,389	4,346

There were three plots of each variety excepting Northwestern Dent, of which there were thirty-one plots.

These tests were carried on in cooperation with the Office of Western Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

* Based on actual dry weight per bushel.

that the reports from these tests would show something regarding the adaptability of these varieties to the various localities.

Out of the two hundred fifty-six farmers to whom these samples were sent, reports were received from fifty-nine and only eighteen of these gave the number of pounds of corn and stover harvested. The yields varied from a few bushels per acre to over a hundred bushels in some cases. In some instances the grain was reported as immature, so the results from this sort of test were not found very satisfactory. The test was valuable, however, in showing the interest which Montana farmers have in corn growing. Evidently there is need for a crop of this sort on the farms of the State.

SUMMARY

1. Corn is the hub of a system of farming in the United States east of the Rocky mountains around which circle all of the economic and social benefits of a diversified system of agriculture. The distribution of farm labor, crop rotation, with all its attendant problems of weeds, insects and plant diseases, soil tillage, moisture conservation, and live-stock production, with its tendency to maintain the fertility of the soil, are all related to the corn crop. Economists have long recognized these relationships in the corn belt of the United States and scientific investigation, together with farm experience, shows them to be equally true in the Northwest under systems of dry farming.

2. A search for types and varieties of corn, growing under essentially the same climatological environments as are furnished by a large portion of Montana's tillable land, has revealed the important and interesting fact that a highly developed and really scientific system of corn culture has long been practiced by the northern tribes of American Indians in general, and by the Upper Missouri River tribes in particular. The latter tribes—Mandan, Hidatsa, and Arikara—were growing extensive crops of corn along the Missouri River in what is now western North Dakota when visited by the first explorers nearly two hundred years ago. The corn grown by these Indians furnishes a basis for study of the characteristics of corns adapted to this climate and a foundation for the upbreeding and development of varieties derived from them.

3. The limiting factors in corn production in Montana are heat units and moisture. Since the surface of the State does not lie in a level plain as does the corn belt of the Middle West but varies greatly in altitude, no types or varieties of corn can be grown with equal success over the entire area. A study of the heat units of the different sections indicates that much of the State is admirably adapted to corn production.

4. A study of some of the plant characteristics of northwestern corns indicates a special adaptation in them to short seasons with relatively low heat units. They differ from the corn belt corns in amount of leaf area, height of stalk, height and size of ear.

5. These distinctive characteristics in corns which are adapted to Montana require different methods of harvesting from those ordinarily used in the corn belt.

6. In the development of corn growing in Montana it is important that farmers familiarize themselves with the characteristics of northern types of corn and that they follow a carefully planned system of seed selection to develop strains well suited to their conditions.

"Aye, the corn, the golden corn, within whose heart there is health and wealth to all nations."—Gov. Oglesby.

Montana Agricultural College Experiment Station

F. B. LINFIELD, Director

BULLETIN No. 108

Second Annual Report of the State Grain Laboratory of Montana

BY

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BOZEMAN, MONTANA

October, 1915

MONTANA AGRICULTURAL COLLEGE
EXPERIMENT STATION
BOZEMAN, MONTANA

NOTICE.—The Bulletins of the Experiment Station will be mailed free to any citizen of Montana on request. Please state whether all the publications are desired as issued or only those specified. Give name and address plainly. All communications to the Experiment Station should be addressed to

THE MONTANA EXPERIMENT STATION,
Bozeman Montana

Second Annual Report
Montana State Grain Laboratory

This report presents a statement of the work carried on by the Montana Grain Laboratory, located at the Montana Agricultural Experiment Station, Bozeman, during the year ending September 30, 1915.

This laboratory was established by an act of the State Legislature of 1913. Its purpose is to study the milling and baking qualities of Montana wheats and to make germination and purity determinations of seed samples sent in by growers and dealers.*

THE YEAR'S WORK

The year's activities in this laboratory may be briefly summarized as follows:

1. Testing and reporting on 2,306 samples for germination and purity, examining 148 samples to determine the grade and dockage, and making tests of 116 additional samples in connection with experimental study,—a total of 2,570 samples handled during the year. The results of the germination and purity tests are given in detail in the later pages of this report.

2. Making 160 laboratory and field tests to find out the percentage of germination of "hard" seeds in legumes. The general practice is to assume that a certain percentage of such seeds (seeds with hard coats which will not germinate within the period regularly allowed) will grow and add this to the percentage regularly germinating. To determine how accurate these general conclusions are, as applied to Montana seeds, a large number of hard seeds of such legumes as clover, alfalfa, and sweet clover were selected and tested through five months in the laboratory and planted in the field to find out what percentage would ultimately grow. The data are not

* A copy of the laws establishing the laboratory and regulating the sale of agricultural seeds, together with the rules and regulations for sampling and sending grain seeds to the laboratory, is contained in Circular 30, which will be sent to any person on request. The report of the first year's work is given in Bulletin 101, which is also available.

given in this report as results with the seeds of any one year may not be representative, and the work will be continued the coming summer.

3. Inspecting thirty-five fields of flax and one field of alfalfa grown from pedigreed seed. Since the ultimate aim of the grain laboratory is to assist in bringing about the use of better seeds, any steps that may be taken to make seeds of superior quality available to growers are worthy of the effort of the laboratory. The seed planted in these flax fields was examined and the fields were inspected to find out the quality of flax from each that would be available for next season's planting. The alfalfa field inspected had been planted with Grimm alfalfa seed and the crop, both growing and after threshing, was inspected for the purpose of registering the seed under the regulations of the Montana Seed Growers' Association.

4. Conducting milling and baking tests of Montana wheats and of standard samples from other localities. The laboratory is working in cooperation with grain laboratories in other states toward the development of standard methods of conducting the various steps in experimental milling and baking study. The results of this work will appear in later publications.

5. During the year special studies have been carried on and pictures assembled for a publication on Montana's worst weeds.

THE SAMPLES RECEIVED

The seed work of the laboratory is heaviest during the winter months, though samples are received every month of the year, as shown in the following list:

October	42	samples	April	253	samples
November	97	"	May	100	"
December	457	"	June	70	"
January	192	"	July	20	"
February	529	"	August	56	"
March	454	"	September	36	"
			Total	2,306	

A comparison of this list with that for 1914 shows an increase of forty samples with a distribution very similar. December, Feb-

FIG. 1. Map of Montana, showing distribution of samples by counties.

TABLE I. VARIETY AND SOURCE OF SEEDS RECEIVED

Variety	1914-15			1913-14		
	Dealers	Farmers	Total	Dealers	Farmers	Total
Corn	62	456	518	106	106	212
Alfalfa	281	229	510	235	304	539
Wheat	147	197	344	69	126	195
Oats	77	106	183	67	193	260
Flax	38	55	93	28	128	156
Barley	35	44	79	45	58	103
Red clover	40	30	70	26	32	58
Timothy	34	33	67	37	62	99
Peas	27	21	48	62	26	88
Sweet clover	11	32	43	8	48	56
Millet	12	19	31	31	15	46
Alsike	13	10	23	12	7	19
Blue-grass	9	5	14	9	1	10
Clover-timothy mixture	2	11	13	1	3	4
Brome grass	6	7	13	5	3	8
Rye	7	2	9	30	8	38
Spelt	5	3	8	6	2	8
Vetch	4	2	6	11	1	12
Redtop	1	4	5			
Rye-grass	0	4	4	8	1	9
Lawn park mixture	2	0	2	12	0	12
Buckwheat	3	0	3	6	1	7
Beets	5	8	13			
Sudan grass	2	7	9			
Beans	2	7	9			
Rape	4	4	8			
White clover	5	2	7			
Orchard grass	3	3	6			
Rutabaga	1	2	3			
Carrots	3	0	3			
Miscellaneous			15			155
Identification, dockage and grade			148			113
No address			10			39
Laboratory experiments			250			20
Total	841	1303	2567	814	1125	2266

ruary, March, and April were the months when the greatest number of samples were received both years.

VARIETY AND SOURCE OF SEED

Table I shows the number of samples of each different kind of seed received and the source—whether from farmers or seed dealers—for the past two years. This shows an increase the second year in the number of samples from both sources, with the greater increase in the number sent in by farmers. During 1913-14, 58 per cent of the samples were from farmers, while in 1914-15 they sent in 61 per cent of the samples.

SAMPLES FROM THE DIFFERENT COUNTIES

In order to show the use being made of the grain laboratory by farmers and dealers in different parts of the State, Table II is given, which shows the number of samples received from each county during the years 1913-14 and 1914-15. It will be noted that Gallatin and Custer counties sent in the greatest number of samples,—302 each. Custer County shows an increase from 154 in 1913-14 to 302 in 1914-15. Other counties showing substantial

FIG. 2. The sample shown above was sold as orchard grass. Purity tests show it to contain 87 per cent meadow fescue and 12 per cent orchard grass.

TABLE II. SHOWING NUMBER AND SOURCE OF SAMPLES

County or State	Alfalfa	Barley	Red clover	Sweet clover	Alsike clover	White clover	Corn	Flax	Millet	Oats	Peas	Rye	Timothy	Wheat	Identification and grade	Miscellaneous	Total 1914-15	Total 1913-14
Beaverhead	5	0	0	1	1	0	0	0	0	0	1	0	0	3	0	0	11	33
Bighorn	14	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	15	9
Blaine	37	2	3	2	1	0	11	6	0	7	0	0	1	17	8	1	96	71
Broadwater	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	2	9
Carbon	0	0	0	0	1	0	0	0	0	3	0	0	1	6	1	1	13	23
Cascade	20	7	0	2	1	0	0	0	2	11	1	0	11	23	1	2	81	35
Chouteau	22	1	0	0	0	0	1	3	0	4	2	0	5	9	1	0	48	52
Custer	45	5	0	3	0	0	210	1	1	9	3	0	1	11	3	10	302	154
Dawson	13	0	0	3	0	0	30	14	4	7	0	1	3	14	1	3	93	91
Deer Lodge	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	3	40
Fergus	16	0	0	3	0	0	0	4	0	1	2	0	3	4	4	1	38	89
Flathead	3	2	0	2	1	1	0	0	0	4	0	0	1	2	3	0	19	35
Fallon	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	25
Gallatin	24	18	26	2	7	1	80	3	1	37	23	1	11	39	12	17	302	360
Granite	0	0	0	0	2	0	0	0	0	5	0	0	1	2	0	1	11	3
Hill	19	14	4	2	1	1	16	23	5	34	4	1	2	43	3	22	194	225
Jefferson	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	8
Lewis and Clark	95	3	19	7	2	0	2	1	0	4	0	1	5	14	8	4	165	134
Lincoln	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Madison	3	0	1	0	1	0	0	0	0	0	0	0	1	3	0	1	10	13
Meagher	1	0	0	0	0	0	0	0	0	0	0	0	0	11	1	1	14	19

TABLE II (Continued). SHOWING NUMBER AND SOURCE OF SAMPLES

County or State	Alfalfa	Barley	Red clover	Sweet clover	Alsike clover	White clover	Corn	Flax	Millet	Oats	Peas	Rye	Timothy	Wheat	Identification and grade	Miscellaneous	Total 1914-15	Total 1913-14
Missoula	1	1	0	0	0	0	0	0	0	5	0	0	1	13	1	2	24	8
Musselshell	19	3	0	0	0	0	11	1	1	6	1	1	2	10	6	11	72	145
Park	20	9	2	0	1	1	0	1	3	5	5	1	4	22	1	5	80	68
Powell	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3	17
Richland	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0
Ravalli	2	0	0	0	0	0	0	2	0	0	2	0	0	4	1	3	14	10
Rosebud	52	0	1	1	0	0	115	1	1	3	0	0	0	11	3	0	188	126
Sanders	1	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	5	5
Sheridan	0	0	0	0	0	0	0	1	0	2	0	0	0	8	0	0	11	11
Silver Bow	3	1	0	0	0	0	0	0	1	3	0	3	0	8	2	3	24	21
Sweet Grass	4	0	0	0	0	0	0	0	0	3	1	0	1	3	1	0	13	13
Stillwater	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
Teton	10	1	0	2	0	1	3	4	0	7	1	0	3	11	15	19	77	67
Valley	9	0	0	3	0	0	19	17	0	13	0	0	1	16	1	3	82	62
Yellowstone	46	9	4	8	1	0	16	4	9	7	2	0	2	18	1	14	141	169
Minnesota	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	
Utah	2	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	5	
North Dakota	2	1	1	1	0	0	1	3	0	1	0	0	0	2	0	0	12	
South Dakota	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	5	
Michigan	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	4	7	
New Jersey	1	0	2	1	1	1	0	0	1	0	0	0	1	0	0	8	16	
Canada	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	

increase this last year in the number of samples sent in are Blaine, Cascade, Lewis and Clark, and Rosebud. During the last year 53 samples were received from outside the State.

GERMINATION WORK

The germination tests are conducted in the standard way. Portions of the sample sent in are carefully taken and these are tested in duplicate, using moist blotters in regular germination chambers. The length of time allowed for the test varies with the kind of seed and ranges from seven to twelve days for grains and clovers to as high as thirty days for some of the grasses. The standards in use by the United States Government and the leading state grain laboratories are being followed in this laboratory, both in methods and in length of time allowed for tests.

To show the germination of grains and grass seeds for the two

TABLE III. SHOWING GERMINATION TESTS OF GRAINS AND GRASSES COMPARED WITH UNITED STATES STANDARDS

Name of seed	Number samples 1914-15	Number samples 1913-14	Average germination 1914-15 (per cent)	Average germination 1913-14 (per cent)	U. S. standard (per cent)	Number of samples above standard 1914-15	Number of samples below standard 1914-15	Highest percentage 1914-15	Lowest percentage 1914-15
Corn	433	212	92.59	90.68	85-90	390	43	100	0
Wheat	324	194	94.39	90.63	90-95	273	51	100	18.50
Oats	179	260	91.45	82.57	90-95	137	42	100	20.
Flax	80	156	98.06	97.50	....	....	....	100	84.5
Barley	77	103	93.01	89.21	90-95	62	15	100	52.5
Timothy	58	99	87.71	82.08	85-90	44	14	98.5	51.
Peas	41	88	87.13	86.20	93-98	22	19	100	16.
Millet	30	46	88.58	85.39	85-90	23	7	100	58.5
Brome grass	12	8	79.70	73.46	75-80	9	3	91	61.
Clover-timothy mixture	11	4	81.90	90.25	....	....	....	93	64.
Blue-grass	8	10	39.46	28.88	45-50	3	5	96.5	15.5
Spelt	8	8	97.31	93.	....	....	....	100	88.
Sudan grass	7	..	73.42	....	....	....	....	80.5	60.5
Rye	7	38	95.14	91.52	90-95	6	1	97.5	89.5
Rape	7	..	94.50	....	90-95	6	1	98.5	87.
Vetch	5	12	67.90	71.39	....	....	....	96.	51.
Rye-grass	4	3	46.62	43.50	....	....	....	61.5	18.5
Buckwheat	3	7	95.66	94.35	90-95	3	0	98.5	93.
Orchard grass	3	..	55.5	....	....	....	....	71.5	37.
Redtop	3	9	79.25	60.62	....	....	....	85.	75.75

years and to compare this with the United States standards, Table III has been prepared. This shows an increase in 1914-15 in the germination percentage of each class of seeds reported except the clover-timothy mixture and the vetch. Some of the most marked

TABLE IV. SHOWING GERMINATION TESTS OF ALFALFA AND CLOVER COMPARED WITH UNITED STATES STANDARDS

Name of seed	Number of samples tested for germination 1914-15	Average germination 1914-15 (per cent) *	Germination 1913-14 (per cent)	Hard seeds (per cent)	U. S. standard of germination (per cent)	Number above standard	Number below standard	Highest germination (per cent)	Lowest germination (per cent)
Alfalfa	489	89.58	90.53	24.80	85-90	405	84	100	67.
Red clover	56	86.86	90.43	22.37	85-90	37	19	99	33.
Sweet clover	38	76.09	78.83	45.68	....	....	....	95.5	24.50
Alsike clover	18	85.33	90.26	21.86	75-80	16	2	97.3	8.5
White clover	4	88.12	....	21.12	75-80	3	1	96.5	67.
Crimson clover	1	81.	....	3.	....	....	....	....	....

* Two-thirds of the hard seeds left at the end of the test are considered good and were reckoned in the number that germinated.

TABLE V. SHOWING GERMINATION TESTS OF VEGETABLE SEEDS COMPARED WITH UNITED STATES STANDARDS

Name of seed	Number of samples	Average germination (per cent)	U. S. standard (per cent)	Number above standard	Number below standard	Highest percentage	Lowest percentage
Beans	9	89.25	90-95	7	2	98.	49.5
Beets	12	72.79	....	....	....	89.5	62.5
Cabbage	2	75.75	90-95	0	2	89.5	62.
Carrots	3	70.83	80-85	0	3	77.	62.
Onions	2	78.	80-85	1	1	91.5	64.5
Parsnips	1	39.	70-75	0	1	....	....
Pumpkin	3	91.5	....	....	....	94.	89.
Rutabaga	3	85.82	....	....	....	94.5	71.
Turnip	1	98.5	90-95	1	0	....	....

increases were: 8.88 per cent in oats, 3.76 per cent in wheat, 3.80 per cent in barley, 5.63 per cent in timothy, and 1.91 per cent in corn. This higher germination capacity was no doubt due to the very favorable ripening season of 1914 which was much warmer and drier than usual.

Table IV shows a comparison of the germination percentage of alfalfa and clover seed for the years 1913-14 and 1914-15 with the United States standards. A study of this table shows a slight decrease in the percentage of germination of alfalfa and clover in 1914-15 as compared with 1913-14. However, the germination shows up well when compared with the United States standards, 83 per cent of the samples of alfalfa seed and 66 per cent of the red clover being above the standards.

Table V shows the germination of the vegetable seeds tested during 1914-15 and the comparison of these tests with the United States standards. The average of the tests is generally below the standard. It should be noted, however, that in most of the cases very few samples were tested so that the averages are not very significant.

THE PURITY WORK

On the average many of the purity tests for the two years are below the United States standards. This does not necessarily mean that the purity of the seeds being planted is below. Many farmers send samples directly from the threshing machine to get information on their germination capacity so as to find out the quality of the seed present. In most cases before such seed is used for planting it is graded up, but the percentage as shown by the sample sent in is low, which reduces the average of the purity tests in the laboratory.

Table VI shows the average purity of the grain and grass seed samples tested during the year and a comparison of these tests with those of the previous year and with the United States standards. The purity of the different seeds, while below the standard in some cases, is still high, being 95 per cent in 90 per cent of the crops.

Table VII shows the result of purity tests of alfalfa and clover seed and a comparison of the tests for 1913-14 and 1914-15 with the United States standards. A comparison of the tests of alfalfa and sweet clover for the two years shows marked improvement in 1914-15. On the average alfalfa was approximately 5 per cent and

TABLE VI. SHOWING THE PURITY TESTS OF GRAINS AND GRASSES COMPARED WITH UNITED STATES STANDARDS

Name of seed	Number samples 1914-15	Number samples 1913-14	Average purity 1914-15 (per cent)	Average purity 1913-14 (per cent)	U. S. standard of purity (per cent)	Number above standard	Number below standard	Highest percentage	Lowest percentage
Wheat	272	194	94.30	94.55	99	58	214	99.90	55.25
Oats	146	260	96.72	97.77	99	59	87	99.90	84.13
Flax	85	156	94.04	91.10	..	..	..	99.64	82.15
Barley	59	103	95.48	94.57	99	17	42	99.50	77.
Timothy	59	99	97.56	96.05	98	38	21	99.96	87.60
Peas	23	88	98.26	98.31	99	20	2	99.50	81.50
Millet	22	46	97.62	95.73	99	10	12	99.9	85.00
Brome grass	12	8	88.04	87.90	90	5	7	95.34	74.10
Clover-timothy mixture	13	4	95.90	98.25	..	..	..	99.80	73.25
Blue-grass	9	10	93.52	94.42	90	7	2	99.5	70.72
Spelt	8	8	94.27	95.06	..	..	..	99.5	76.6
Sudan grass	9	0	95.24	....	..	..	..	98.5	85.04
Rye	8	38	95.26	92.20	99	0	8	98.	87.05
Rape	7	..	98.60	....	..	..	..	99.8	95.9
Vetch	3	12	96.90	97.25	..	..	..	99.	92.7
Rye-grass	4	3	96.93	91.50	..	..	..	99.	94.75
Buckwheat	3	7	99.01	95.01	99	1	2	99.7	98.64
Orchard grass	3	..	64.65	....	..	2	1	99.	2.67
Redtop	4	9	89.93	89.92	..	..	..	96.26	80.

TABLE VII. SHOWING THE PURITY TESTS OF ALFALFA AND CLOVER COMPARED WITH UNITED STATES STANDARDS

Name of seed	Number of samples tested for purity	Average purity of samples 1914-15 (per cent)	Average purity of samples 1913-14 (per cent)	U. S. standard (per cent)	Number above standard	Number below standard	Highest percentage	Lowest percentage
Alfalfa	486	94.81	89.97	98	184	302	99.84	24.
Red clover	59	95.03	96.43	98	27	32	99.80	65.66
Sweet clover	36	87.34	78.15	....	....	....	99.90	51.60
Alsike clover	21	85.67	95.15	95	11	10	99.50	36.
White clover	5	92.72	....	95	3	2	99.	79.84
Crimson clover	1	98.42	....	98	1	....	....	....

sweet clover 9 per cent cleaner the second year. The purity of red clover was slightly lower and that of alsike nearly 10 per cent lower in 1914-15 than in 1913-14.

WEEDS MOST FREQUENTLY PRESENT

To indicate the weed pests most common on Montana farms, the following list has been prepared, giving the names of the weed seeds most commonly found in the ten crops most generally grown:

Alfalfa, 510 samples: 228 contained Russian thistle; 215, lamb's-quarters; 112, green foxtail; 81, sweet clover; 70, dodder; 66, wild buckwheat; 61, pigweed; 60, gumweed; 44, mustard; 32, sticktight; 30, wild sunflower; 24, curled dock; 23, chicory; 22, marsh elder; 20, plantain.

FIG. 3. The sample shown above was purchased as timothy and alsike. The test showed no alsike present. The dark, round seeds are lamb's-quarters.

Wheat, 344 samples: 41 contained wild buckwheat; 31 wild oats; 27, mustard; 27, cow cockle; 15, wild sunflower; 12, lamb's-quarters; 9, corn cockle; 7, pigweed; 6, fanweed; 5, quack-grass; 5, false flax; 3, Russian thistle; 3, green foxtail; 3, ragweed; 3, roadside thistle.

Oats, 183 samples: 53 contained wild oats; 24, wild sunflower; 24, wild buckwheat; 24, lamb's-quarters; 19, mustard; 15, cow cockle;

FIG. 4. The sample shown above was sold as sweet clover seed. The purity test showed it to be 88 per cent alfalfa. Sweet clover was selling at 25 cents a pound and alfalfa at 17 cents.

6, false flax; 6, fanweed; 5, Russian thistle; 3, corn cockle; 2, marsh elder; 2, curled dock; 2, pigweed, 2, green foxtail; 1, quack-grass.

Flax, 93 samples: 25 contained false flax; 22, mustard; 9, wild sunflower; 7, lamb's-quarters; 6, pigweed; 5, yellow foxtail; 3, green foxtail; 3, wild buckwheat; 3, peppergrass; 2, bull thistle; 2, ragweed; 2, cow cockle; 2, dodder; 2, Russian thistle; 1, quack-grass.

Barley, 79 samples: 13 contained wild oats; 5, wild buckwheat; 3, hare's-ear mustard; 2, curled dock; 2, wild sunflower; 2, mustard; 2, green foxtail; 2, lamb's-quarters; 1, western wheat grass; 1, cow cockle; 1, false flax; 1, pigweed; 1, Russian thistle; 1, fanweed; 1, tumbling mustard.

Red clover, 70 samples: 26 contained lamb's-quarters; 16, plantain; 15, sheep-sorrel; 15, green foxtail; 13, curled dock; 5, Russian thistle; 4, chess; 4, hare's-ear mustard; 4, catchfly; 4, ragweed; 4, marsh elder; 4, gumweed; 4, mustard; 3, wild buckwheat; 3, patience dock.

Timothy, 67 samples: 22 contained lamb's-quarters; 15, five-finger; 14, peppergrass; 6, false flax; 5, mustard; 3, green foxtail; 3, curled dock; 3, plantain; 3, smartweed; 3, shepherd's purse; 3,

FIG. 5. Alfalfa containing a large percentage of yellow trefoil, also marsh elder, wild buckwheat, gumweed, Russian thistle, and dodder.

FIG. 6. Sample of alfalfa containing a large percentage of dodder seed.

yarrow; 2, dragonhead; 2, catchfly; 2, yellow foxtail; 2, pigweed.

Sweet clover, 43 samples: 13 contained lamb's-quarters; 6, mustard; 6, marsh elder; 5, Russian thistle; 5, wild sunflower; 4, green foxtail; 4, curled dock; 3, wild buckwheat; 3, pigweed; 3, gumweed; 2, dodder; 2, false flax; 2, roadside thistle; 1, wild oats; 1, knotweed.

Millet, 31 samples: 8 contained green foxtail; 6, yellow foxtail; 4, ragweed; 4, mustard; 3, lamb's-quarters; 3, wild buckwheat; 2, smartweed; 2, pigweed; 2, green foxtail; 1, wild oats; 1, cow cockle; 1, sunflower; 1, catchfly; 1, hare's-ear mustard; 1, barnyard grass.

Alsike clover, 23 samples: 10 contained sheep-sorrel; 7, lamb's-quarters; 3, plantain; 3, five-finger; 1, green foxtail; 1, pigweed; 1, dodder; 1, curled dock; 1, sticktight; 1, peppergrass; 1, shepherd's

FIG. 7. A set of seeds of Montana's worst weeds. The five across the top are the noxious weeds prohibited by the State law, and the remaining fifteen are those most commonly found. These sets are put up at the grain laboratory and offered for sale at cost.

TABLE VIII. SHOWING 50 MOST COMMON WEEDS FOUND IN SEEDS OF 12 COMMON CROPS TESTED FOR PURITY

Common name	Scientific name	Number of weed seeds in crop seed samples												
		Alfalfa	Barley	Red clover	Sweet clover	Alsike clover	White clover	Flax	Millet	Oats	Rye	Timothy	Wheat	Total
Lamb's-quarters	Chenopodium album	215	2	26	13	7	4	7	3	24	2	22	12	337
Russian thistle	Salsola tragus	228	1	5	5	..	..	2	2	5	1	..	3	252
Green foxtail	Setaria viridis	112	2	15	4	1	1	3	8	2	..	3	3	154
Wild buckwheat	Polygonum convolvulus	66	5	3	3	..	..	3	3	24	3	..	41	151
Mustard	Brassica sp.	44	2	4	6	..	..	22	4	19	2	5	27	135
Wild oats	Avena fatua	1	13	..	1	..	..	1	1	53	..	..	31	101
Wild sunflower	Helianthus sp.	30	2	..	5	..	..	9	1	24	3	1	15	90
Pigweed	Amaranthus retroflexus	61	1	..	3	1	1	6	2	2	..	2	7	86
Sweet clover	Melilotus sp.	81	..	..	..	..	..	..	..	1	..	..	2	84
Dodder	Cuscuta sp.	70	..	1	2	1	..	2	..	..	..	..	..	76
Gumweed	Grindelia squarrosa	60	..	4	3	..	..	..	..	..	..	2	..	69
False flax	Camelina sativa	11	1	..	2	..	..	25	..	6	..	6	5	56
Cow cockle	Saponaria vaccaria	8	1	..	..	..	..	2	1	15	1	..	27	55
Curled dock	Rumex crispus	24	2	13	4	1	..	..	..	2	..	3	..	49
Plantain	Plantago sp.	20	..	16	1	3	4	1	..	..	..	3	..	48
Marsh elder	Iva xanthiifolia	22	..	4	6	..	..	1	..	2	..	..	2	37
Sticktight	Lappula sp.	32	..	1	..	1	..	..	..	1	..	..	2	37
Sheep-sorrel	Rumex acetosella	5	..	15	..	10	3	..	..	..	..	1	..	34
Ragweed	Ambrosia artemisiifolia	12	..	4	1	..	..	2	4	1	..	..	3	27
Fanweed	Thlaspi arvense	10	1	1	..	..	..	1	..	6	1	1	6	27
Slender wheat grass	Agropyron tenerum	19	..	..	1	..	..	1	..	1	..	2	1	25
Chicory	Chicorium intybus	23	..	1	1	..	..	..	..	..	..	..	..	25
Peppergrass	Lepidium apetalum	2	..	..	..	1	..	3	..	1	..	14	2	23
Yellow foxtail	Setaria glauca	6	..	1	..	..	..	5	6	1	..	2	..	21
Five-finger	Potentilla sp.	2	..	..	..	3	..	..	..	..	..	15	..	20
Smartweed	Polygonum persicaria	12	..	1	..	..	..	1	2	..	..	3	..	19

TABLE VIII (Continued). SHOWING 50 MOST COMMON WEEDS FOUND IN SEEDS OF 12 COMMON CROPS TESTED FOR PURITY

Common name	Scientific name	Number of weed seeds in crop seed samples												
		Alfalfa	Barley	Red clover	Sweet clover	Alsike clover	White clover	Flax	Millet	Oats	Rye	Timothy	Wheat	Total
Roadside thistle	Circium discolor	13	..	1	2	..	..	..	..	..	..	..	3	19
Quack-grass	Agropyron repens	9	..	1	..	..	..	1	..	1	..	1	5	18
Catchfly	Silene noctiflora	5	..	4	..	..	2	..	1	..	..	2	..	14
Corn cockle	Agrostemma githago	..	..	..	..	..	..	..	..	3	..	..	9	12
Yellow trefoil	Medicago lupulina	12	..	..	..	..	..	..	..	..	..	..	..	12
Mallow	Malva rotundifolia	11	..	..	1	..	..	..	..	..	..	..	..	12
Knotweed	Polygonum aviculare	10	..	1	1	..	..	..	..	..	..	..	..	12
Hare's-ear mustard	Conringia orientalis	4	3	4	..	..	..	..	1	..	1	..	..	13
Witch-grass	Panicum capillare	9	..	..	..	..	1	..	..	..	..	1	..	11
Knapweed	Centuria picris	11	..	..	..	..	..	..	..	..	..	..	..	11
Barnyard grass	Echinochloa crusgalli	8	..	1	..	..	..	..	1	..	..	..	1	11
Patience dock	Rumex patientia	8	..	3	..	..	..	..	..	..	..	..	..	11
Chess cheat	Bromus secalinus	2	..	4	..	..	..	..	..	1	..	..	2	9
Bindweed	Convolvulus sepium	4	..	2	1	..	..	1	..	..	..	..	..	8
Canada thistle	Circium arvense	7	..	..	..	..	..	..	..	..	..	..	..	7
Shepherd's purse	Capsella Bursa-pastoris	1	..	2	..	1	..	..	..	..	..	3	..	7
Bull thistle	Circium lanceolatum	3	..	1	..	..	..	2	..	..	..	..	..	6
Western wheat grass	Agropyron smithii	1	1	..	..	..	..	..	..	..	1	1	2	6
Dragon head	Dracocephalum sp.	2	..	1	..	..	..	..	..	..	..	2	..	5
Maple-leaved goosefoot	Chenopodium hybridum	3	..	..	1	..	..	..	..	..	..	1	..	5
Evening primrose	Oenothera biennis	2	..	..	..	1	..	..	..	..	..	1	..	4
Wild bergamot	Monarda fistulosa	..	..	2	..	1	..	..	..	..	..	1	..	4
Yarrow	Achillea millefolium	..	..	..	1	..	..	..	..	..	..	3	..	4
Ox tongue	Picris echioides	3	..	..	1	..	..	..	..	..	..	..	..	4
Total number seed samples		510	79	70	43	23	7	93	31	183	9	67	344	1459

purse; 1, evening primrose; 1 wild bergamot; 1, mayweed; 1, mustard.

The data given in this list show a marked increase in the percentage of seeds of serious weed pests. This was probably due to the greater rainfall during the early growing months of 1914. The United States weather records show that for the months of May and June there was 2.75 inches more rainfall in 1914 than in 1913. Heavy rainfall almost always stimulates weed growth.

In comparison with the 1913-14 determinations, there was increase in 1914-15 as follows: the number of samples containing dodder increased from 10.5 to 13.7 per cent, those containing mustard from 7.2 to 8.6 per cent, while the number of samples of alfalfa that contained Russian thistle grew from 32.6 per cent in 1913-14 to 44.7 per cent in 1914-15,—an increase of 12.1 per cent. Wild oats occurred quite frequently, being found in 28.9 per cent of the oat samples and 16.4 per cent of the barley samples. Mustard was commonly found, being second in point of frequency of occurrence in flax and sweet clover, third in wheat, fourth in millet, fifth in oats and timothy, and sixth in barley. Quack-grass and fanweed, two very serious weed pests, did not occur frequently.

THE FIFTY MOST COMMON WEEDS

To indicate something of the variety of weed seeds which are found in the samples of seed sent in, Table VIII has been prepared, showing the occurrence of fifty of the most common weeds found in 1,459 samples of seeds of the most common crops. An examination of reports from other stations shows that many of these are the common weed pests of other parts of the country. In the exchange of seed and in many other ways weed pests very quickly spread over the entire country.

Montana Agricultural College
Experiment Station

F. B. LINFIELD, Director

BULLETIN NO. 109

Thirteenth Annual Report of the State Entomologist of Montana

The Cottonwood Leaf Beetle, *Lina scripta* Fab.

BY

R. A. COOLEY

BOZEMAN, MONTANA
FEBRUARY, 1916

MONTANA AGRICULTURAL COLLEGE EXPERIMENT STATION

BOZEMAN, MONTANA

NOTICE.—The Bulletins of the Experiment Station will be mailed free to any citizen of Montana on request. Please state whether all the publications are desired as issued or only those specified. Give name and address plainly. All communications to the Experiment Station should be addressed to

THE MONTANA EXPERIMENT STATION,
Bozeman Montana

Thirteenth Annual Report of the State Entomologist of Montana

INSECT PESTS OF 1915

The amount of damage caused by insects in Montana during the season of 1915 was greater than in any other year since the office of state entomologist was created. The outstanding feature of the year was the abundance of grain pests, the worst of which was the army cutworm. This insect alone destroyed at least 100,000 acres of grain.

The more important insects which came to our notice during the year are briefly discussed and recorded.

ACARINA

Leaf Blister Mite (*Eriophyes pyri* Pgst.). For several years the leaf blister mite has been increasingly injurious in the apple orchards of the Bitter Root Valley and during the past season it is reported to have done more damage than any other orchard pest.

Clover Mite (*Bryobia pratensis* Garman). Several letters were received complaining that this mite was invading houses. In one instance it was reported as injuring clover lawns.

Red Spider (*Tetranychus bimaculatus* Harvey). In the vicinity of Flathead Lake red spiders were unusually injurious to raspberries.

Spotted Fever Tick (*Dermacentor venustus* Banks). One of the striking features of the season of 1915 was the appearance of this tick in large numbers in eastern Montana where it previously had attracted but little attention. A number of cases of spotted fever were also reported for the first time from this locality.

ORTHOPTERA

Grasshoppers (*Acrididae*). Not a single report of grasshopper injury was received during the season, which is rather remarkable considering the abundance of insects in general.

Coulee Cricket (*Peranabrus scabracollis* Thom.). This large, clumsy cricket, which attracted much attention in Washington during the past summer, also appeared in western Montana on the Flathead Reservation. In several places it caused considerable injury.

HEMIPTERA

Capsid injury to wheat (*Capsus ater* Linn). An unusual injury

to winter wheat was reported from Plains in April. An examination disclosed numerous black capsids sucking the juice from the plants, which became spotted at the point of attack. But little loss resulted from the attack.

Green Apple Aphis (*Aphis pomi* De G.). Present in about normal numbers.

Cabbage Aphis (*Aphis brassicae* L.). Not as injurious as in 1914.

Grain Root Aphis (*Forda occidentalis*). This plant louse occurs very commonly upon the roots of wheat and is often blamed for the injury caused by *Brachycolus tritici*. In no instance has *Forda* been observed to seriously injure its host plant.

Western Grain Aphis (*Brachycolus tritici* Gillette). This aphid which has been increasing and spreading in Montana for several years was highly injurious to winter wheat, in some instances completely destroying entire fields. Considerable time was spent in studying this important pest and its life history and a method of control have been worked out. Absolutely clean summer fallow is a sure preventive of injury.

Aphids in heads of grain. During August daily reports were received of aphids infesting heads of grain. Generally the specimens sent in were badly mashed and accurate determination was not always possible. Genera recognized were *Macrosiphum*, *Toxoptera* and *Aphis*. Little damage was done as the grain was well advanced when the insects first appeared in numbers.

Sugar Beet Root Louse (*Pemphigus betae* Doane). Investigations concerning this important sugar beet pest were carried on under the Adams fund as in previous years. It is hoped that a system of irrigation may be worked out which will reduce injury from this insect to a minimum.

Woolly Aphis (*Schizoneura lanigera* Hanseman). In the Bitter Root Valley this insect appears to be spreading and becoming more firmly established each year.

LEPIDOPTERA

Army Cutworm (*Chorizagrotis auxiliaris* Grote). Many sections of the State were devastated by armies of cutworms belonging for the most part to the above named species. This was by far the

most destructive insect of the year and is more fully discussed elsewhere in this report.

Mourning Cloak Butterfly (*Euvanessa antiopa* L.). The spiny caterpillars of this species were abundant in many parts of the State and were frequently sent in with the report that they were feeding on elm and willow foliage.

Noctuid working in cottonwood bark (*Porosagrotis rileyana*). The larva of this species produces an unusual type of injury as it feeds upon the green bark of the cottonwood tree. It was sent in from Silver Bow County.

Army Worm (*Leucania unipuncta* Haworth). The notorious army worm which caused such widespread damage in 1914 in the East, was found in Montana for the first time this season. It was highly injurious to oats in the one locality in which it appeared.

Polyphemus Moth (*Telea polyphemus* Cramer). This showy moth is apparently working westward. It was taken for the first time in Montana at Huntley in 1914 and in 1915 it was sent in from Columbus and Bozeman.

Red Humped Caterpillar (*Schizura concinna* S. & A.). Specimens of this species were sent in from western Montana where they were said to be injuring fruit trees.

DIPTERA

Lip Bot Fly (*Gostrophilus haemorrhordalis* Linn.). This species which was reported as far west as Billings in 1914 was taken during the past season in Yellowstone Park and in Sixteen Mile Canyon. At both places it was said that it had never been troublesome in previous years.

Mosquitoes (*Culicidae*). Because of recent popular demand for information concerning mosquitoes, this important group of insects was given special attention in 1915. Studies of the life history and methods of control were carried on at several points and collections of larvae and adults were made wherever possible. From the results of our studies, it appears that the following species are the most important from an economic standpoint: *Aedes sylvestris*, *A. spenceri*, *A. nigromaculus*, *A. curriei*, *A. pullatus* and *Culex tarsalis*.

Wheat Stem Maggots. Considerable injury to winter wheat was caused by dipterous maggots mining in the leaves and in the sheath. A study of this class of pests showed that at least three species were

involved,—*Meromyza americana* Fetch, *Meromyza nigriventris* Macq., and *Cerodontha femoralis* Meig.

COLEOPTERA

Beet Carrion Beetle (*Silpha bituberosa* Lec). During April and May this pest appeared in destructive numbers at many places in the sugar beet district around Billings. In some instances young beets were so badly injured that a very poor stand resulted and in one instance wheat was attacked.

Lesser Clover Weevil (*Phytonomus nigrirostris* Fab.). The first appearance of this insect in Montana was noted in the Jocko Valley during the past season. This insect closely resembles the alfalfa weevil in appearance and the manner of its attack but is not nearly as destructive.

Eyed Elater (*Alaus oculatus* Linn). A specimen of this strange-appearing insect was sent us from Custer. It is the first one to be received into our collection.

Bumble Flower Beetle (*Euphoria inda* L.). In the Yellowstone Valley this beetle was again reported as injuring corn by working in the kernels at the tip of the ear.

False Wireworm (*Eleodes extricata* var. *convexicollis* Blaisdell). False wireworms were very abundant in many localities and in several instances were injurious to newly sprouted grain.

Cottonwood Leaf Beetle (*Lina scripta* Fab.). During July and August this was the insect concerning which there was the greatest demand for information. Cottonwood and willow trees were attacked in all parts of the State. While this pest seldom kills trees outright, it causes the foliage to turn brown and greatly weakens the vitality of the tree. A drawing of the adult beetle appears on the cover of this publication.

Dung Beetle (*Aphodius inquinatus* Abst.). For the past two seasons this insect has appeared in enormous numbers and has attracted much attention. In the fall on warm, still days the air frequently appears filled with the adults, and horse droppings are completely worked over in a few minutes.

Wireworms (*Elateridae*). Numerous reports of wireworm injury were received during the course of the year, including injury to potatoes, corn and grain.

Some of the Principal State Interests in Entomology in 1915

THE ARMY CUTWORM

The outstanding feature of the year in Montana from the standpoint of the entomologist was an unprecedented outbreak of the army cutworm (*Chorizagrotis auxiliaris*). On April 2 we received a report of the presence of this insect in eastern Montana and after this many other reports came in from other parts of the State in rapid succession. The outbreak was quite general and severe. While some cutworms were reported from western Montana practically all of the damage was done east of the divide.

This insect is a very general feeder and refuses almost no plants that come in its way, yet practically all of the damage was done to fall wheat so far as our reports indicate. An attempt has been made to form an estimate of the acreage of wheat eaten off and we believe that fully 100,000 acres was destroyed. A large part of this was seeded again late in April or in May and in many cases good crops of spring wheat were harvested. Where reseeding was done the loss was only the cost of again preparing the soil and reseeding, together with any difference in the value of the harvested crop. In many cases, however, fields were only partly destroyed and the farmer was often in doubt whether or not he should reseed. The loss on the acreage that was not reseeded was considerable. A considerable amount of damage was done also to miscellaneous crops such as flax, alfalfa, and some tilled crops and plants in gardens.

Early in the outbreak an assistant was sent to an infested field for the purpose of performing tests with the use of poisoned bran mash with and without citrous fruit juices added. These tests showed that the bran mash without the fruit juices added was very effective and accordingly we proceeded to base our recommendations for the season on this mixture. As the season advanced we gained further experience with the use of this poison bran mash, all of which was distinctly in its favor; in fact we had no complaints of failure to get good results with its use and many very favorable comments were received.

To meet the emergency and supply the information needed a brief circular of information was hurried through the press. A circular letter was mailed to the newspapers of the State as follows:

Bozeman, Montana, April 16, 1915.

To the Newspapers of Montana:

This office desires to cooperate with the press of Montana in preventing, so far as possible, the damage to fall grain and other crops by the army cutworm.

We believe that many crops are being damaged without the owners knowing it. An emergency circular giving the most up-to-date information has just been printed and will be sent to all who request it. This gives directions for examining the field and gives remedies which we have used with much success this season. We wll be glad to send these in bundles to those who will distribute them to farmers who need them.

In some localities there is need for community cooperation. Bankers and business men should aid the farmers to organize. In places where bad outbreaks are occurring the poisoned bran mash should be mixed up in quantity and distributed to the farmers at cost.

Very respectfully,

(Signed) R. A. Cooley,

Entomologist.

Besides this special letters were written to some newspapers. Other letters were written to bankers and elevator operators. The result was that we received many requests for the circular. Bundles of from ten to fifty were sent to different parties all over the State. The circular was held in type and reprinted twice.

The correspondence on the subject of recognizing and controlling the army cutworms became heavy. As many as forty-eight letters were written in a single day.

Two assistants from this office spent much of their time in the field cooperating with the farmers during this outbreak. There can be no doubt that in several instances a sum greater than the entire appropriation made to the office of the State Entomologist was saved on a single farm, and it is clear that throughout the State the amount of the whole appropriation ($2,000) was saved many times over.

Advantage was taken of the presence of this insect in such unusual numbers to secure further information regarding its life-

history. Accordingly certain experiments and studies were undertaken under the Federal Adams fund, which have resulted in gathering facts of the greatest importance. These will be prepared for publication during the winter.

THE ALFALFA WEEVIL

General interest has continued in the effort to prevent the introduction of the alfalfa weevil into Montana from Utah, Idaho, and Wyoming where it now exists. Several reports of the weevil in Montana have been looked up, but in no instance have we found this insect, excepting in shipments coming from Utah. The work of the lesser clover weevil (*Phytonomus nigrirostris*) closely resembles that of the alfalfa weevil and the larvae of the two insects are very much alike. A destructive colony of the lesser clover weevil appeared in the western part of the State this year and there is small wonder that farmers were alarmed.

Every effort is being made to keep the alfalfa weevil out of Montana. If it should be introduced and if it should be as injurious here as it is in Utah, where it is continuing to be very destructive year after year, it would be a very serious thing for Montana where the alfalfa crop takes such a prominent place in the agriculture of the State.

Until further information is received, at least, it will be the policy of this office to recommend maintaining a reasonable quarantine in order that the chances of introducing this insect may be reduced to a minimum.

THE WESTERN WHEAT APHIS

The outbreak of army cutworms and the newspaper comments upon it in various parts of the State directed unusual attention to other pests of wheat. Farmers in looking for cutworms found other insects and wrote us about them. Some of these are of considerable importance. A number of reports of damage by the western wheat aphis, *Brachycolus tritici*, were received. This insect was first brought to our attention several years ago and as practically nothing was known regarding its life-history and the means of controlling it we have given special attention to it. Wheat plants affected by the wheat aphis have a characteristic appearance which is easily recognized when once seen. Young infested plants show a thick-

ening and broadening of the leaf blades. A very few aphids on a plant may have a surprisingly injurious effect. Some plants show in the later stages of injury a characteristic twisting of the stem and a deformed head. The injury often appears only in spots in the field, but sometimes entire fields are affected and much damage results.

The only literature on the life-history and control has been issued by this office. We have been able to recommend an effective method of control and we feel that when grain growers become familiar with the insect and the way to control it the damage will be much reduced.

One important scientific paper on this subject has been published during the year* and it is intended to print and distribute a bulletin during the coming year.

A NEW CUTWORM

A little known cutworm (*Euxoa* neat *quadridentata*) was brought to our attention by Senator T. O. Larson of Choteau who reported damage to wheat near Brady in Teton County. A considerable number of acres of grain had been severely damaged and some alarm was felt in the neighborhood. This insect was studied in the insectary where valuable information was received and it will be given further attention as we have opportunity. It is not probable that it will be found to be nearly so important a pest as the army cutworm.

THE WHEAT STEM MAGGOT

Farmers in western Montana reported a peculiar injury to grain in May. Injured plants when examined were found to contain small, white maggots in the axis. These turned out to be the young of the wheat stem maggot, *Cerodontha femoralis.* These maggots bore down through the stem, completely destroying the plant, and go out through the crown into the earth where they pupate. The eggs are laid on the leaves by the parent flies which are very small and not easily found.

The living insects were studied in the insectary and the stages of development were worked out. It is hoped that further study may devise a method of controlling this little known pest.

* Parker, J. R. The western wheat aphis. In Journal of Economic Entomology, Vol. 9, No. 1, 1916.

Along with this insect we found also sheath maggots (*Meromyza americana* and *M. nigriventris*) which were doing some damage, but less than the stem maggots. A study of these maggots will be continued.

THE SPOTTED FEVER TICK

In the Twelfth Annual Report of the State Entomologist a brief review of the status and organization of the work on the spotted fever tick is given. In the past particular attention has been given to the tick in western Montana where in certain localities the spotted fever exists in its most virulent form. This work, now under the supervision of the Montana State Board of Entomology, is being pushed with energy and much success. Good progress is being made in the eradication of the tick and the reduction of the number of fever cases and deaths.

During the season of 1915 the tick took on a new and larger significance in Montana by the appearance in the eastern part of the State of a considerable number of cases of the spotted fever in localities where so far as we know none had occurred before. This has led to a greatly increased interest in the tick in several counties and it is now necessary that a thorough study of the situation be made.

MOSQUITOES

One of the most striking developments in official entomology in Montana in recent years has been the increasing and insistent demand for information regarding the best procedure to be adopted to secure relief from mosquitoes. We have had demands from towns and many individuals for assistance. Very little has been done in the study of mosquitoes under conditions such as we have in Montana where irrigation is so extensively practiced and where the mosquito fauna is so different from that in eastern states. It is assumed by many who write in for information that all it is necessary to do is to state what is being done in other localities. As a matter of fact, while some good can be done by drainage of stagnant water and oiling where mosquito larvae are found, it is necessary to know much more than we now do regarding the kinds of mosquitoes present and the habits of the more important ones in order that we may intelligently meet the situation.

A study of mosquitoes has been taken up and will be pushed as rapidly as possible with the limited funds at our disposal. A great good can be done for Montana with a relatively small amount of money spent in this direction and much annoyance to man and domestic animals may be prevented. It is hoped that within a year or two a preliminary report may be printed.

FOUL BROOD OF THE HONEY BEE

The situation with respect to the foul brood of bees remains unchanged excepting that it is being found in new localities. An attempt to secure the passage of a foul brood law by the Fourteenth Legislative Assembly failed.

A large number of colonies have been destroyed and in the part of the State most seriously affected the industry has been greatly injured. It is not easy to predict what will be the final result of the ravages of this disease if no legislation is passed. If we may assume that the results will be much the same as in other localities we may say that before many years the disease will be all over the State and the number of colonies will be greatly reduced.

Montana State Entomologist Law

Be it enacted by the Legislative Assembly of the State of Montana:

Section 1. The entomologist of the Montana Agricultural College and Experiment Station shall be known as the State Entomologist of Montana.

Section 2. It shall be the duty of the State Entomologist to conduct field investigations of the injurious insects of fruits, vegetables, grains, grasses, forage crops, including clover and alfalfa, root crops, shade trees, ornamental plants, and any other insects that may become injurious. When it becomes known to the State Entomologist that an outbreak of an insect has occurred in any part of the State, it shall be his duty, so far as is possible without conflicting with his other duties, to go to the scene of the outbreak, determine its extent and seriousness, and, when necessary, publish or make public demonstration of the best remedies to be employed.

Section 3. The Entomologist shall make an annual report to the Governor of the State, on or before the first day of January, which report shall be published by the Experiment Station as one of its regular bulletins, and shall contain a report of his work and expenditures under this Act.

Section 4. The State Entomologist shall receive no compensation for his services other than what he may receive from the Montana Agricultural College and Experiment Station, but his actual traveling expenses not to exceed three hundred dollars* shall be paid, and such sum is hereby annually appropriated for the purposes of this act out of the moneys of the State Treasury, not otherwise appropriated.

Upon the certification of the Secretary of the Executive Board of the Montana Agricultural College and Director of the Agricultural Experiment Station, the State Auditor is authorized to issue warrants to cover the traveling expenses of the State Entomologist while engaged in carrying out the provisions of this Act.

Section 5. This Act shall take effect and be in force from and after its passage and approval by the Governor.

Approved March 4, 1903.

* This sum has been increased from time to time by the various sessions of the legislature and the appropriation made by the last legislature was $2,700.00.

MONTANA AGRICULTURAL COLLEGE
EXPERIMENT STATION

F. B. LINFIELD, Director

BULLETIN NO. 110

Dry Farm Grain Tests in Montana

BY

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AND

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United States Department of Agriculture

BOZEMAN, MONTANA
FEBRUARY, 1916

MONTANA AGRICULTURAL COLLEGE
EXPERIMENT STATION
BOZEMAN, MONTANA

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THE MONTANA EXPERIMENT STATION,
Bozeman Montana

Dry Farm Grain Tests in Montana

Experiments with cereals have been conducted cooperatively since 1908 at the Judith Basin substation,* Moccasin, Mont., by the Office of Cereal Investigations of the Bureau of Plant Industry and the Montana Agricultural Experiment Station. The memorandum of understanding between the two parties specifies that—

"The objects of these cooperative investigations shall be (1) to improve the cereals of the northern Plains region by introducing better varieties than those now grown, especially with regard to drought resistance, yield, quality, earliness, etc., and (2) to conduct such other experiments as may seem advisable for the accomplishment of the greatest possible good to the dry-land interests of the State."

This bulletin presents briefly the results of these investigations, together with such conclusions as they seem to warrant. All experiments here reported have been conducted under dry-farming conditions.

Description of the Judith Basin

The following rather detailed description of the Judith Basin and the conditions obtaining there allows comparison with other parts of the State where it is believed that the substation results are applicable.

TOPOGRAPHY

The Judith Basin is an area of nearly 2,000,000 acres of tillable bench land lying in the western half of Fergus County, Montana.

* The Judith Basin substation was established in 1908 by the Montana Agricultural Experiment Station, in cooperation with the Bureau of Plant Industry. Professor F. B. Linfield has been director of the State station since before the substation was started. Professor Alfred Atkinson, head of the agronomy department at the State station, has had direct charge of the substation for the State. Mr. J. M. Stephens has been superintendent of the substation since its establishment. Mr. E. L. Adams was in charge of the experiments with cereals from 1909 to 1912. On his transfer to another station in May of the latter year, the writer was appointed agent in the Office of Cereal Investigations to take charge of the cooperative cereal work and on October 1, 1912, was appointed scientific assistant.

The basin, so called because it is nearly surrounded by mountains, is about 75 miles from east to west and 50 miles from north to south. The Little Belt mountains form the southern and western boundaries. The Highwood mountains and the Bad Lands or breaks of the Missouri River lie to the north. The North and South Moccasin, the Judith and the Snowy Mountains form the eastern boundary. The basin is drained by the Judith River and its tributaries. Part of the land along the river and creek bottoms can be irrigated, but by far the larger part of the district is classed as dry land.

Until a few years ago the Judith Basin was a range country. The only land farmed was along the river and creek bottoms, while the bench lands were used to pasture great herds of cattle and sheep. Within the last ten years practically all the tillable land in the basin has been brought under cultivation. Winter wheat is raised almost exclusively, although a few of the farmers are gradually working into a more diversified system of farming.

SOILS

The soils of the Judith Basin are rather non-uniform. The surface is a dark, heavy clay loam of limestone origin, which varies in depth from a few inches to 3 feet. When wet it becomes very sticky and because of its adhesive character can be plowed only with a disk plow. Analysis of the soil shows that apparently it is quite rich in available plant food. The subsoil to a depth of 30 feet is composed of limestone gravel closely cemented together and is of such character as not to allow the storage of water or the development of roots.

Table I. Composition of the soil at the Judith Basin substation, as determined by mechanical analysis.

	First foot per cent	Second foot per cent
Fine gravel	0.9	1.1
Coarse sand	2.7	2.3
Medium sand	4.4	3.2
Fine sand	13.3	10.4
Very fine sand	13.4	11.6
Silt	40.7	33.3
Clay	24.3	38.1

The composition of the soil on the substation as determined by mechanical analysis is shown in Table I. The stickiness of the soil is due largely to its high percentage of silt and clay, 40.7 and 24.3 per cent, respectively, in the surface foot.

NATIVE GRASSES

In their original state these bench lands are covered with grass. The most important native grass is grama grass (*Bouteloua oligostachya*). Buffalo grass (*Bulbulis dactyloides*), western wheat grass (*Agropyron smithii, A. occidentale*), slender wheat grass (*Agropyron tenerum*), and needle grass (*Stipa comata* and *S. viridula*) are also found but are not as abundant as the grama grass. The grasses on the bench land make a very good pasture but seldom grow tall enough to be cut for hay.

CLIMATE

Before discussing crop yields or attempting to draw any conclusions it is necessary to have in mind the climatic factors affecting crop growth. The most important of these factors are (1) seasonal and annual rainfall, (2) the seasonal evaporation, and (3) temperature, with special reference to the length of the growing season as limited by the spring and fall frosts. With the exception of the rainfall records from 1898 to 1908, all data on these factors here presented have been obtained at the substation at Moccasin.

PRECIPITATION

Table II gives the annual and average precipitation by months in the vicinity of Moccasin for the eighteen years from 1898 to1915, inclusive. Previous to 1909 the records were taken at Utica, 7 miles southwest of the substation. Since that time they have been taken at the substation by the Biophysical Laboratory of the Bureau of Plant Industry. The average annual precipitation for eighteen years (Table II) is 16.66 inches. During this time the maximum precipitation in any one year was 23.76 inches (1909), and the minimum, 10.42 inches (1900).

The peculiar soil conditions existing at Moccasin and more or less throughout the Judith Basin make it nearly impossible to store any appreciable amount of moisture in the soil. The seasonal distribution of the rainfall, therefore, is of great importance. The growing season for spring grains at Moccasin extends from about

Table II. Monthly, seasonal, and annual precipitation in inches in the vicinity of Moccasin, Mont., during the eighteen years from 1898 to 1915, inclusive.*

[Data from the records of U. S. Weather Bureau and the Biophysical Laboratory of the Bureau of Plant Industry.]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal	Total
1898	0.70	0.27	1.91	1.12	5.87	5.80	3.16	0.67	0.47	1.25	1.14	0.59	15.95	22.95
1899	1.69	.38	.92	2.29	3.33	1.22	2.57	1.31	.28	1.15	.11	.88	9.41	16.13
1900	.45	.35	.21	2.85	1.04	.44	.70	2.20	.82	.86	.29	.21	5.03	10.42
1901	.40	.20	.57	1.65	3.82	3.97	1.97	.90	2.42	1.39	T	3.22	11.41	20.51
1902	.14	.24	.45	1.12	1.41	3.28	1.84	.67	.32	.18	2.04	.25	7.65	11.94
1903	.50	.24	1.11	2.29	1.82	2.81	2.57	.81	2.42	.05	.44	.65	9.49	15.71
1904	.18	.22	.79	1.14	1.94	1.73	3.25	.42	.12	.54	.50	.24	8.06	11.07
1905	.19	.16	.62	.75	1.97	2.82	3.19	.27	.83	.39	.50	T	8.73	11.69
1906	.55	.63	.43	.16	2.61	2.66	.93	2.00	.99	.70	.42	.68	6.56	12.76
1907	1.34	.08	.61	.43	3.21	6.75	3.51	1.47	.73	.20	T	T	13.90	18.33
1908	.55	.49	.98	.61	7.31	2.45	.20	1.18	1.41	6.27	T	.22	10.57	21.67
1909	.90	.08	1.22	1.03	1.34	5.97	2.54	4.21	4.47	.49	.30	1.21	10.88	23.76
1910	.09	.74	.10	1.31	2.40	1.69	1.10	2.02	2.54	1.36	1.26	.48	6.50	15.09
1911	.58	.55	.54	1.66	2.98	2.55	.50	6.34	1.37	1.94	1.76	.68	7.69	21.45
1912	.88	.60	.81	1.43	3.94	.64	1.92	1.27	1.63	1.68	.14	.06	7.93	15.00
1913	.89	.09	.20	.79	2.64	4.77	1.12	.51	1.01	1.63	.93	.38	9.32	14.96
1914	.47	1.35	1.12	1.19	2.91	4.64	.64	.65	1.11	.74	.64	.21	9.38	15.67
1915	.76	.08	2.69	1.43	2.12	3.97	3.54	.92	2.65	.85	1.01	.66	11.06	20.68
Average	.62	.38	.85	1.29	2.93	3.23	1.96	1.55	1.42	1.20	.64	.59	9.41	16.66
Maximum ...	1.69	1.35	2.69	2.85	7.31	6.75	3.54	6.34	4.47	6.27	2.04	3.22	15.95	23.76
Minimum ...	.09	.08	.10	.16	1.04	.44	.20	.27	.12	.05	T	T	5.03	10.42

* Precipitation records previous to 1909 were taken at Utica, Mont., 7 miles southwest of the substation; since that date they have been taken at the substation.

April 1 to August 10. Since the precipitation that falls after the first of August has little effect on the yields of the cereal crops, the growing season is considered as extending from April 1 to July 31. The average precipitation in this 4-month period during eighteen years is 9.41 inches, or 56 per cent of the average annual precipitation.

Table III gives the average monthly, annual, and seasonal precipitation at the Judith Basin substation in the nine years from 1907 to 1915, inclusive, the years during which experiments have been conducted at Moccasin. This table has been compiled from the monthly and annual records given in Table II.

Since winter wheat usually is sown during August and September the record of seasonal precipitation for winter wheat should include these months. Table IV shows the annual and average precipitation in the calendar year and in the crop year for winter grains (August 1 to July 31) and the seasonal precipitation for small grains (April 1 to July 31) in the eight years from 1908 to 1915, inclusive. In the crop year for winter wheat the figures are for the twelve months ending July 31 of the year indicated; that is, they show the precipitation affecting the crop of winter wheat harvested that year.

To permit comparison of the precipitation at Moccasin with that in other portions of the State, the average annual precipitation at 25 different points in Montana, including Moccasin, is given in Table V. These data were obtained from the records of the U. S. Weather Bureau as published in Bulletin No. 99 of the Montana Experiment Station.* In nearly all cases the average is for sixteen years, 1898-1913, inclusive.

Table V shows that the precipitation at Moccasin is a little higher than in eastern Montana but is about the same as that of the central and western parts of the State. The locations of the stations for which data are given are shown in figure 1.

EVAPORATION

Of the climatic factors that influence crop growth, evaporation is probably next in importance to seasonal precipitation. Evaporation records have been taken at Moccasin since 1909. The evapora-

* Burke, Edmund, and Pinckney, Reuben M. A report on Montana climate. Montana Agricultural Experiment Station Bulletin 99. 1914.

Table III. Average monthly, seasonal, and annual precipitation in inches at Moccasin, Mont., during the nine years from 1907 to 1915, inclusive.

[Data from the records of U. S. Weather Bureau and the Biophysical Laboratory of the Bureau of Plant Industry.]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal	Total
Average	0.72	0.45	0.92	1.09	3.20	3.72	1.67	2.06	1.86	1.68	0.67	0.43	9.69	18.51
Maximum ...	1.34	1.35	2.69	1.43	7.31	6.75	3.54	6.34	4.47	6.27	1.76	1.21	13.90	23.76
Minimum	.09	.08	.10	.43	1.34	.64	.20	.51	.73	.20	T	T	6.50	14.96

Table IV. Annual and average precipitation in inches during the calendar year and in the crop year for winter grains (August 1 to July 31), and seasonal precipitation for spring grains (April 1 to July 31) at the Judith Basin Substation in the eight years from 1908 to 1915, inclusive.

	1908	1909	1910	1911	1912	1913	1914	1915	Aver.
Calendar year	21.67	23.76	15.09	21.45	15.00	14.96	15.67	20.68	18.53
Crop year for winter grains (Aug. 1 to July 31)[a]......	14.99	22.16	18.11	17.02	22.31	15.28	16.78	17.94	18.07
Seasonal for spring grains (Apr. 1 to July 31)........	10.57	10.88	6.50	7.69	7.93	9.32	9.38	11.06	9.16

[a] Figures in each column are for the twelve months ending on July 31 of the year indicated.

tion is determined from a free water surface, the method being the one usually employed where the Biophysical Laboratory of the Bureau of Plant Industry is cooperating.*

Table V. Average precipitation in inches at 25 stations in Montana, including Moccasin, for the years indicated.

(Data from records of the U. S. Weather Bureau.)

Station	Length of period	Average precipitation Inches
EASTERN MONTANA:		
Ekalaka	16 years (1898-1913)	13.32
Glendive	16 years (1898-1913)	15.50
Poplar	16 years (1898-1913)	14.12
Glasgow	16 years (1898-1913)	13.95
Miles City	16 years (1898-1913)	14.07
Forsyth	10 years (1904-1913)	13.32
Crow Agency	16 years (1898-1913)	15.37
Billings	9 years (1905-1913)	14.15
CENTRAL MONTANA:		
Chinook	16 years (1898-1913)	12.39
Havre	16 years (1898-1913)	12.96
Fort Benton	15 years (1898-1912)	13.71
Great Falls	16 years (1898-1913)	15.86
Lewistown	16 years (1898-1913)	19.77
Red Lodge	16 years (1898-1913)	19.76
Livingston	15 years (1896-1910)	14.33
Bozeman	16 years (1898-1913)	18.28
WESTERN MONTANA:		
Helena	16 years (1898-1913)	14.06
Adel	16 years (1898-1913)	21.35
Augusta	16 years (1898-1913)	16.50
Cut Bank	16 years (1898-1913)	14.76
Kalispell	16 years (1898-1913)	15.32
Missoula	16 years (1898-1913)	15.31
Butte	16 years (1898-1913)	14.65
Dillon	16 years (1898-1913)	17.86

Summary

Average at 8 stations in eastern Montana	14.23
Average at 8 stations in central Montana	15.88
Average at 8 stations in western Montana	16.22
Average at all stations	15.44
Moccasin, 16 years (1898-1913)	16.46

* Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 88, p. 16-20, 1910.

FIG. 1. Map of Montana, showing locations of stations of U. S. Weather Bureau.

Table VI. Monthly precipitation and evaporation in inches from a free water surface at the Judith Basin substation from April to September of each year from 1909 to 1915, inclusive.

(Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.)

Year	April		May		June		July		August		September		Total		Ratio
	Precipitation	Evaporation	Precipitation	Evaporation	Precipitation	Evaporation	Precipitation	Evaporation	Precipitation	Evaporation	Precipitation	Evaporation	Precipitation	Evaporation	
1909	1.03	3.00	1.34	4.66	5.99	6.00	2.54	7.22	4.21	7.06	4.47	4.67	19.58	32.61	1:1.6
1910	1.31	5.18	2.40	5.61	1.69	7.21	1.10	8.28	2.02	7.38	2.54	6.48	11.06	40.14	1:3.6
1911	1.66	4.10	2.98	5.94	2.55	5.13	.50	7.31	6.34	6.35	1.37	3.41	15.40	32.22	1:2.1
1912	1.43	2.62	3.94	4.14	.64	6.39	1.92	5.97	1.27	6.23	1.63	3.42	10.83	28.77	1:2.6
1913	.79	3.89	2.64	4.23	4.77	4.90	1.12	6.37	.51	7.35	1.01	5.83	10.84	32.58	1:3.0
1914	1.19	3.21	2.91	4.85	4.64	4.43	.64	7.45	.65	7.24	1.11	5.10	11.14	32.27	1:2.8
1915	1.43	4.70	2.12	4.61	3.97	4.35	3.54	4.89	.92	6.51	2.65	3.43	14.63	28.49	1:1.9
Average	1.28	3.81	2.92	4.86	3.04	5.49	1.82	6.78	2.27	6.87	2.11	4.62	13.35	32.44	1:2.4

Records are taken for six months, April to September, inclusive. In Table VI the evaporation and precipitation in these months are given for the seven years from 1909 to 1915, inclusive. This table also gives the total and average precipitation and evaporation in this period, with the ratio of the total precipitation to total evaporation.

The greatest evaporation in any one year, as shown in Table VI, was 40.14 inches (1910). While the seasonal precipitation (April 1 to September 30) in 1910 was not quite as low as in some of the other years, the ratio between the precipitation and evaporation was wider than in any other year. The average ratio for the seven years is 1 :2.4. A comparison of this ratio with the ratios for the diffferent years gives a very fair basis for judging the seasonal conditions under which the experiments for each year were conducted.

WIND

Measurements of the wind velocity have been taken at the Judith Basin substation by the Biophysical Laboratory of the Bureau of Plant Industry since 1910. The records are taken during six months, April to September, inclusive. The anemometer stands near the evaporation tank, at a height of about 2 feet above the surface of the ground. Table VII gives the average wind velocity

Table VII. Average wind velocity in miles per hour at the Judith Basin substation, by months, from April to September of each year, 1910 to 1915, inclusive.

(Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.)

Year	April	May	June	July	Aug.	Sept.	Average
1910	9.0	6.8	6.3	5.9	6.0	4.0	6.33
1911	7.8	8.0	5.4	5.9	5.9	5.3	6.38
1912	6.6	7.6	5.7	5.1	6.4	6.7	6.35
1913	8.7	6.5	5.3	5.0	5.4	6.5	6.23
1914	6.3	7.5	6.4	5.5	6.0	7.2	6.48
1915	7.6	7.5	6.6	5.1	4.9	5.9	6.26
Average	7.7	7.3	6.0	5.4	5.8	5.9	6.35

from April to September in the six years from 1910 to 1915, inclusive.

Table VII shows that April has the highest average wind velocity, 7.7 miles per hour. This velocity decreases through May, June, and July, but increases again slightly in August and September. The 6-year average velocity in the six months is 6.35 miles per hour.

TEMPERATURE

Table VIII gives the mean, maximum, and minimum temperatures at the Judith Basin substation by months from April to September of each year from 1909 to 1915, inclusive. The highest average mean temperatures occur in July and August, 63° F., and the highest average maximum in August, 77° F. Temperatures as high as 95° F. are rare in the Judith Basin. When hot weather occurs it lasts only for a short time. Hot, drying winds are uncommon. In only one year since the station was started have hot winds done any damage to the growing crops.

Table IX gives the dates of the last spring and first fall frosts and the number of days in the frost-free period in each year from 1909 to 1915, inclusive.

The longest frost-free period was 150 days, in 1909, and the shortest 82 days, in 1910. The latest frost in the spring was on June 4, in 1911. The average date of the last frost in the spring is May 20. The earliest frost in the fall in the seven years occurred on August 23, in 1910. The average date of the first frost in fall is September 13. The average length of the frost-free period in the seven years is 116 days.

The Judith Basin Substation

LOCATION

The Judith Basin substation is located 2 miles west of the town of Moccasin, in Fergus County, in the central part of the Judith Basin and about the geographical center of the State. The latitude is about 47 degrees N. and the longitude 109 degrees 45 minutes W. The substation farm is Section 16, Township 15 North, Range 14 E. A branch of the Great Northern Railway from Great Falls to Billings passes through one corner of the station section.

Table VIII. Mean, maximum, and minimum temperatures in degrees F. at the Judith Basin substation by months from April to September of each year from 1909 to 1915, inclusive.

(Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.)

Year	April			May			June			July			August			September			Seasonal mean
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	
1909	35	44	25	49	60	38	58	68	47	63	74	50	65	78	50	59	68	49	55
1910	49	65	34	51	62	41	60	74	47	68	82	53	62	75	47	53	63	41	57
1911	38	51	26	48	59	37	60	71	47	62	77	45	58	70	47	50	62	38	52
1912	43	55	31	50	60	37	61	74	45	61	75	47	62	76	47	48	60	35	54
1913	43	55	31	49	63	38	60	73	48	62	76	48	65	81	49	55	72	40	56
1914	42	56	29	51	65	37	57	69	45	68	83	51	62	77	45	56	71	40	56
1915	50	62	37	49	59	38	52	62	42	58	69	46	66	81	51	49	59	38	54
Average	43	55	30	49	61	38	58	70	46	63	76	49	63	77	48	53	65	40	55

Table IX. Dates of killing frosts, the last in spring and first in fall, with length of frost-free period in each year from 1909 to 1915, inclusive, at the Judith Basin substation.

(Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.)

Year	Last in spring	First in fall	Frost-free period	Year	Last in spring	First in fall	Frost-free period
			Days				Days
1909	May 15	Oct. 12	150	1913	May 19	Sept. 9	112
1910	June 2	Aug. 23	82	1914	May 12	Sept. 12	123
1911	June 4	Sept. 15	103	1915	May 16	Sept. 11	118
1912	May 12	Sept. 15	126	Average	May 20	Sept. 13	116

DESCRIPTION

The station farm consists of 640 acres. One corner of the farm is creek bottom and the remainder is level, tillable bench land. About 320 acres is under cultivation and the rest is used for pasture. The elevation at the substation is 4,300 feet.

It is believed that the results obtained at Moccasin are applicable to the whole of the Judith Basin and in a general way to the twenty million acres of dry land throughout the State, where the annual rainfall and its distribution are the chief factors limiting crop growth.

SCOPE OF THE EXPERIMENTS

The experiments with cereals may be divided into two groups, plat tests and nursery tests. The plat tests consist of varietal, date-of-seeding, and rate-of-seeding tests of winter and spring wheat and spring oats, barley, and flax. In different years the number of varieties under test has varied from 75 to 125. The number of plats in the date-of-seeding and rate-of-seeding tests has ranged from 40 to 60, so that the total number of experiments has varied from 115 to 185.

The nursery work at Moccasin covers two general lines, (1) the introduction and testing of new varieties, and (2) experiments in improvement of cereals. New varieties are usually tested in nursery rows before being grown in plats. This makes possible the testing of a large number of varieties with much less time and labor than would be necessary in larger plats.

The effort in the improvement work has been to select individual heads representing desirable types. These selections usually are made from the varieties that have given the best results in the plat tests. These selections are multiplied and tested for yield and other desirable characteristics, such as length and stiffness of straw, freedom from shattering, etc. The poor selections are discarded and the promising ones increased.

The number of rows has varied from 256 in 1909 to 840 in 1911. Most of these are devoted to the improvement work. Since 1911 the number of rows has been reduced as the poor selections are discarded and the promising ones increased.

EXPERIMENTAL METHODS

That portion of the substation farm used for plat work is divided

into blocks 132 feet wide and 617 feet long which are separated by roads 1 rod wide. These blocks may be divided into tenth-acre, twentieth-acre, or fiftieth-acre plats, each 132 feet or 8 rods long.

PLAT EXPERIMENTS

Size of Plats

All of the varieties in 1908 and 1909 and nearly all in 1910 were grown on tenth-acre plats. In 1911 and 1912, because of the shortage of land, all crops except winter wheat were grown on twentieth-acre plats. The tenth-acre plats are 2 rods wide and 8 rods long, with alleys 3.5 feet wide between the plats and roads 1 rod wide between the series. The twentieth-acre plats are 1 rod wide and 8 rods long, with 20-inch alleys.

In 1913 part of the winter wheat varieties were grown on acre plats. These plats were 8 rods wide and 20 rods long. The spring wheat varieties were grown in fiftieth-acre plats and the rest of the spring cereals in tenth-acre plats. In 1914 and 1915 part of the winter wheat varieties were grown in acre plats and the spring cereals in fiftieth-acre plats. The fiftieth-acre plats are 6 feet wide and 8 rods long with 18-inch alleys. This plat is actually one fifty-fifth of an acre in area, but as some moisture and plant food are drawn from the alleys it seems fair to consider them as fiftieth-acre plats in computing acre yields.

Replication of Plats

From 1908 until 1913 all varieties were grown in single tenth-acre or twentieth-acre plats. In every year except 1908 check plats of a standard variety were grown. In 1913 the spring wheat varieties were grown in replicated fiftieth-acre plats and in 1914 and 1915 all crops except the winter wheat varieties in acre plats were grown in this way. A 6-foot drill is used and one drill-width across the series (8 rods) covers one-fiftieth acre. As stated before, these plats are really one fifty-fifth of an acre in area, but in computing acre yields they are considered as one-fiftieth of an acre. In the replication method in use at the Judith Basin substation five plats of each variety are grown. These plats are distributed throughout the space devoted to the test. In computing the yields of the varieties grown in replicated plats the average yield of the 5 fiftieth-acre plats of any one variety is obtained and the acre yield then computed.

Preparation of the Land

With few exceptions all the varietal tests of cereals have been conducted on fallow ground. In 1908 the crops were sown on sod broken in 1907. In 1910 it was necessary to grow the barley varieties on land that had been cropped to barley the previous year. In 1911 and 1912 the flax varieties were sown on ground that had produced a crop the year previous. In all other cases the varietal tests were conducted on fallow ground.

Where the land was continuously cropped the plowing was done in the spring and a good seed bed prepared before sowing. The fallow ground was usually plowed in June or July after weeds and volunteer grain were well started. Plowing was done with a disk plow to a depth of 7 to 8 inches. It was found that if the land was worked down smooth after plowing there was likely to be considerable blowing of the soil during the winter. Consequently, it has been the custom to leave the land rough until spring, when it is worked down with the disk and spike-tooth harrows to form a good seed bed.

In the preparation of the land an effort has been made to follow actual farm practices as closely as possible. In some cases it has been necessary to do some cultivating and hand weeding in order to keep the land uniform, but on the whole the plats have not reecived any more cultivation than would be given under good farming conditions.

Treatment of Crops

The seeding has been done with an 8-foot double-disk and a 6-foot single-disk drill. On each drill the spouts were 6 inches apart. After seeding no cultivation has been given the plats. In some years it was necessary to cultivate the alleys and roads in order to kill the weeds. In the 18-inch alleys between the fiftieth-acre plats the weeds were pulled by hand and no cultivation was necessary.

Harvesting is done with a binder. The grain is shocked on the plats and remains there until it is threshed. The threshing is done with a small thresher with a 26-inch cylinder. Since the varieties have been grown in the replicated plats, one plat of each variety has been carefully rogued and the crop from this plat threshed with the small nursery thresher. By this method it is possible to avoid the mixing that takes place in the larger thresher and thus obtain pure seed of each variety.

Crop Records

The first notes taken after sowing are on date of coming up. After this notes are taken on the stand of the different varieties. Since all the varieties of any one cereal are seeded at the same rate and on the same date all stands are usually uniform, but any differences are noted. Any disease that may appear is noted, as is also the percentage of lodging. Records are kept of the dates of heading, ripening, and cutting of each variety.

Nursery Methods

The new varieties tested in the nursery are usually grown in 3-rod or 8-rod rows, depending on the quantity of seed available. In some cases it is possible to discard part of the varieties the first year, but usually they are grown two years. By this time it is possible to discard the poor varieties, while the most promising ones are increased.

In the selection work the starting point is usually the head row. From the head row the good selections are grown in 3-rod or 8-rod rows, depending on the quantity of seed available. After being tested in 8-rod rows for two years it is usually possible to discard the poor selections. The more promising ones either are increased or continued in 8-rod rows. When they are increased they are usually grown in a hundredth-acre or fiftieth-acre plat for one or two years before being grown in the regular varietal test.

The selections in head rows are sown by hand. In all the other nursery work the seeding is done with the grain drill. In seeding the 3-rod and 8-rod rows alternate holes in the drill are closed and the rows sown 1 foot apart. The rows are harvested by hand and threshed with the nursery thresher. Complete notes are taken on all selections and varieties.

EXPERIMENTS WITH WHEAT

Wheat is the most important grain crop in Montana. For this reason the experiments with this crop have been more extensive than those with any of the other cereals. The experiments at the Judith Basin substation have included plat and nursery tests with both spring and winter wheat. Rate-of-seeding and date-of-seeding experiments with these cereals have also been conducted.

WINTER WHEAT

In 1915 the production of winter wheat in Montana exceeded

FIG. 2. Winter wheat test plots. Crail Fife on the right and Crimean or Turkey Red on the left.

the production of spring wheat by nearly 3,000,000 bushels. In the Judith Basin winter wheat is grown almost exclusively. In the eastern part of the State winter wheat can be grown only in favorable years. In some years good yields are produced, but there is likely to be winter-killing, so that it is not a sure crop. It is not possible to draw any definite line marking the boundary of the winter wheat area in the State. At Forsyth, in the eastern part of Rosebud County, winter wheat can be grown successfully. East of Forsyth it can hardly be recommended as a good crop to grow, although it has been grown as far east as Glendive.

Where winter wheat can be grown successfully it yields more than spring wheat. It is thought that the results obtained from the winter wheat tests at the Judith Basin substation are applicable wherever the crop can be grown in the State.

Varietal Test of Winter Wheat

The varietal test of winter wheat at Moccasin has included the varieties and strains that have given the best results in the winter wheat section of the Great Plains area. The varieties have been grown on fallow ground each year. The plats have been either one-tenth acre or one acre.

In the fall of 1908, 15 varieties and strains of winter wheat

were obtained from McPherson, Kans. These were sown September 18, which is too late for best results in the Judith Basin. Owing to the late seeding there was considerable winter-killing. Six varieties sown ten days later winter-killed entirely. In 1909, nine more varieties and strains were obtained from the Nephi (Utah) substation.

Table X gives the annual and average yields of twenty-four varieties of winter wheat that have been grown at the Judith Basin substation during periods of varying length in the seven years from 1909 to 1915, inclusive. In this table the varieties are grouped according to their relationships. Within the groups they are arranged alphabetically.

As stated previously, the yields in 1909 were lowered on account of winter-killing. The average survival on the winter wheat plats in the spring of 1909 was 41 per cent. Wheat that was sown early did not suffer from winter-killing and yielded from 45 to 50 bushels per acre.

In 1910 and 1911 the seasonal precipitation was below the average, but, as there was no hot weather and most of the seasonal rainfall came in May and June, good yields were obtained.

In 1912, the rainfall in May was above normal, while the precipitation for June was nearly 3 inches below normal. As a result the winter wheat varieties headed early. A local hailstorm on July 11, when the wheat was fully headed, reduced the yields about 50 per cent.

In 1913 conditions were about normal and an average crop was produced. In 1914 there was abnormally heavy rainfall in May and June, followed by unusually hot, dry weather in July. This caused the wheat to ripen early. The yields were the lowest recorded at the station with the exception of those produced in 1912, and the quality of grain was poor.

In 1915, the temperature during the growing season was below normal while the rainfall was more than 2 inches above normal. The yields produced were the highest ever recorded at the station.

In the fall of 1912 and of each succeeding year the seven leading varieties of winter wheat were seeded on acre plats. This change was made in order to test these varieties on a large scale under actual field conditions, and to have seed of the best varieties available for distribution. Table XI gives the annual and average yields of

Table X. Annual and average yields of varieties of winter wheat on the Judith Basin substation, 1909 to 1915, inclusive.

Group and variety	C. I. No.	Yield per acre (bushels)									
		1909	1910	1911	1912	1913	[a]1914	[a]1915	Average		
									3 years 1909-11	5 years 1909-13	7 years 1909-15
Crimean group:											
Alberta Red	2979		37.0	38.5	16.0	[a]34.0	25.5	49.1			33.3[b]
Armavir	1355		36.3	30.0							
Beloglina	1543	26.7	40.5	29.8					32.3		
Do.	1544	25.0	32.7	34.8	8.0				30.8		
Crimean	1432	23.7	34.0	40.3	12.7	31.8			32.7	28.5	
Do.	1433	15.3	32.4	34.0	9.5				27.2		
Do.	1435	30.7	40.1	33.3	18.0	[a]28.0	23.8	49.5	34.7	30.0	31.9
Do.	1436	24.2	34.2	32.7	11.5	30.0			30.4	26.5	
Do.	1437	27.5	37.4	40.2	14.7	[a]35.3	22.7	51.0	35.0	31.0	32.7
Do.	1559	25.0	35.3	40.0	10.0	[a]35.0	22.4	49.2	33.4	29.0	30.9
Kharkov	1442	20.7	46.2	43.3	17.0	[a]33.1	25.5	49.0	36.7	32.0	33.5
Do.	1583	32.8	48.0	41.3	22.7	[a]31.1	24.5	49.4	40.7	35.2	35.7
Torgova	1539	25.0	30.4	29.2					28.2		
Turkey	1532	18.3	29.4	33.7	14.0	29.0			27.1	24.9	
Do.	1571	23.3	41.6	37.7	21.5	29.7			34.2	30.7	
Do.	1576		28.4	28.7							
Do.	1558	21.7	43.7	43.7	22.7	[a]32.1	25.8	49.2	36.4	31.8	34.1
Do.	2998		23.6	30.7	13.6	35.5					
Hungarian group:											
Bacska	1562		28.0	26.7							
Weissenberg	1563	24.7	35.3	33.7					31.2		
Miscellaneous:											
Currell	2903		22.6	31.7							
Ghirka Winter	1438		23.6	33.0							
Koffoid	2997		19.8	34.2							
Zimmerman	2907		25.4	33.0							

[a] Yields from acre plats.
[b] Six years only, 1910-1915.

these seven varieties in acre plats during the three years, 1913, 1914, and 1915. The land where these varieties were grown was not always in the best of tilth. The plan was to give the land only such cultivation as it would receive under average farm conditions. The yields from the acre plats were not as high as the yields of the same varieties grown in the smaller plats.

Table XI shows that with the exception of Crimean, C. I. No. 1435, there was little difference in the average yields of the different varieties. In 1913, Kharkov, C. I. No. 1583, was grown on the outside plat in the series. There was considerable blowing of the soil during the fall and winter and in consequence the stand and yield of this plat were reduced.

Table XI. Annual and average yield of 7 varieties of winter wheat grown in acre plats at the Judith Basin substation, Moccasin, Mont., in the three years from 1913 to 1915, inclusive.

Variety	C. I. No.	Yield per acre (bushels)			
		1913	1914	1915	Average
Alberta Red	2979	34.0	25.5	49.1	36.2
Crimean	1435	28.0	23.8	49.5	33.8
Do.	1437	35.3	22.7	51.0	36.3
Do.	1559	35.0	22.4	49.2	35.5
Kharkov	1442	33.1	25.5	49.0	35.9
Do.	1583	31.1	24.5	49.4	35.0
Turkey	1558	32.1	25.8	49.2	35.7

Summary of Winter Wheat Yields

Of the varieties that have been tested in plats, only 6 have been grown during the full period of years. One additional variety, the Alberta Red, has been grown for six years. The yields of these 7 varieties are from acre plats in 1913, 1914, and 1915, and are not quite as high as they would have been had the varieties been grown in small plats under more favorable conditions.

Table X shows that, of these varieties, Kharkov, C. I. No. 1583, has the highest average yield, 35.7 bushels per acre. This variety

was also the highest in average yield in the 3-year and 5-year periods. A study of the yields of Kharkov, C. I. No. 1583, shows that in 1909 and 1910 it was the highest yielding variety. In 1909 the stands of the varieties were reduced by winterkilling and the Kharkov came through with a higher percentage of survival than any of the others. In 1910, when the seasonal precipitation was the lowest recorded at the substation, the yield of Kharkov was considerably higher than that of any of the other varieties.

Leading Varieties of Winter Wheat

Of the 24 varieties of winter wheat that are listed in Table X no less than 18 belong to the Crimean group. These wheats are bearded with glabrous white glumes and hard red kernels. They were imported into this country from southern Russia and are now extensively grown in the central Great Plains area and the Pacific Northwest. They are the most important varieties of winter wheat grown in Montana.

The Turkey is probably the best known variety, but the Kharkov and Crimean scarcely can be distinguished from it. The Kharkov, which has been the leading variety of winter wheat at the Judith Basin substation, is thought to be a superior strain of the Crimean group. It seems to be more hardy and to stand drought better than the other varieties, although there are not very large differences in the average yield of the Kharkov, Turkey, and Crimean varieties.

The Kharkov wheat has been increased for distribution among the farmers. This work was started in 1912 and since that time about 2,000 bushels have been sold from the station to farmers for seed. This seed has been distributed not only among the farmers in the Judith Basin but in other parts of the State as well. Reports obtained from farmers who are growing this variety in different parts of the State indicate that they consider it better than other similar varieties. Some farmers claim that the Kharkov yields from 5 to 10 bushels more than the common strain of Turkey which they have been growing.

The average dates of seeding, heading, and maturity, the height, yield per acre of grain and of straw, and weight per bushel of the 7 leading varieties of winter wheat are given in Table XII.

Date-of-Seeding Test

Date-of-seeding tests with winter wheat have been conducted

Table XII. Average dates of seeding, heading, and maturity, days from seeding to maturity, height, yield of grain and straw, and weight per bushel of 7 leading winter wheat varieties at the Judith Basin substation, Moccasin, Mont., in seven years, 1909 to 1915, inclusive.

Variety	C. I. No.	Average date			Days from seeding to maturity	Height	Yield per acre		[a]Weight per bushel
		Sown	Headed	Ripe			Grain	Straw	
						Inches	Bushels	Pounds	Pounds
Alberta Red	2979	Sept. 1	June 27	August 4	338	39	[a]33.3	3,292	59.6
Crimean	1435	do.	do.	do.	338	38	31.9	3,660	59.8
Do.	1437	do.	do.	do.	338	39	32.6	3,680	60.1
Do.	1559	do.	do.	do.	338	38	30.9	3,690	60.1
Kharkov	1442	do.	do.	do.	338	38	33.5	3,690	59.6
Do.	1583	do.	do.	do.	338	37	35.6	3,550	60.1
Turkey	1558	do.	do.	do.	338	38	34.1	3,660	60.5

[a] Average for six years, 1910-1915, inclusive.

for six years. During the first three years, Turkey (C. I. No. 1558) was used, while during the last three years Kharkov (C. I. No. 1583) was sown. The dates included have ranged from August 1 to October 15. The results of these tests have been rather variable, due, no doubt, to the variations in climatic conditions during August and September of the different years. In 1909 the earliest seeding, August 1, gave the best results. In this year there was considerable winterkilling in the late-sown plats. On the average, the best results have been obtained from plats sown between August 12 and September 20. It may happen in some years that there is not enough moisture in the soil in August and September to germinate the wheat and give it a good start. When this condition occurs late seeding is likely to be better than early seeding.

Table XIII gives the data that have been recorded in the date-of-seeding test. From this table it will be seen that in the six years the early September seeding (September 1 to 7) has produced the highest average yield. There is little difference between the yields produced from seeding at this date and from seeding either about August 15 or September 15. It is probable that seeding between August 10 and September 20 will give good results. Wheat seeded after the later date is likely to get a poor start in the fall and therefore to winterkill.

Table XIII shows that the average yield of plats sown October 1 and October 15 is from 10 to 11 bushels per acre less than that of plats sown September 1 to 7.

Table XIII. Annual and average yields in bushels per acre obtained in a date-of-seeding test with winter wheat at the Judith Basin substation during the six years from 1909 to 1914, inclusive.

Date of seeding	Yield in bushels per acre							
	1909	1910	1911	1912	1913	1914	Average	
							1911-14	yrs. sown
August 1-7	60.5	36.0	30.3	[a]	28.0	[a]		38.7
August 12-17 ...	32.0	38.6	31.0	16.7	32.5	28.7	27.2	29.8
September 1-7...	24.5	36.5	35.6	20.0	46.0	28.7	32.3	31.9
September 15-20.	25.2	[a]	35.3	16.3	35.0	30.0	29.1	28.3
October 1	0	24.0	30.0	17.5	26.8	23.3	24.4	20.3
October 15	[a]	[a]	29.3	9.1	17.3	28.8	21.1	21.1

[a] Not sown.

In all the varietal tests at the Judith Basin substation an effort has been made to sow the winter wheat early; that is, between August 10 and Sepember 10. In 1908, the only year when there was much winterkilling, the seeding was late because the seed was not available earlier.

Rate-of-Seeding Test

Rate-of-seeding tests with winter wheat were started in 1909 and conducted for six years. During the first three years, Turkey (C. I. No. 1558) was used, while during the last three years Kharkov (C. I. No. 1583) was sown. The rates of seeding ranged from 2 to 8 pecks per acre. Table XIV contains the data that have been obtained from these tests. This table shows that there is but little difference in the yields produced from the 3-peck and the 4-peck rates of seeding, the rates from which the highest yields have been obtained.

Because of the free tillering of winter wheat it is not necessary to seed heavily in order to get a good stand. Seeding more than 4 pecks to the acre not only reduces the yield but also the quality of the grain. Three pecks is the usual rate used in the Judith Basin and is the rate at which all of the plats in the varietal tsts were sown.

Table XIV. Annual and average yields in bushels per acre obtained in a rate-of-seeding test with winter wheat at the Judith Basin substation during the six years 1909 to 1914, inclusive.

Rate of seeding	Yield in bushels per acre							
	1909	1910	1911	1912	1913	1914	Average	
							1909-14	1910-13
2 pecks	16.4	36.5	33.3	16.7	27.7	25.0	25.8	28.5
3 pecks	32.0	41.5	37.3	18.6	32.5	28.8	31.8	32.5
4 pecks	35 4	38.0	35.0	21.7	30.3	27.8	31.2	31.2
5 pecks		35.0	35.0	19.0	25.7		28.5	28.7
6 pecks	23.6	31.6	35.3	20.4	26.7		27.4	28.5
8 pecks	22.8	28.2	36.8	20.7	27.0		26.9	28.2

Nursery Tests

The nursery work with winter wheat at the Judith Basin substation has included the testing of new varieties and strains and the making and testing of selections. New varieties are usually grown in nursery rows to determine their hardiness and something of their yielding powers before they are tested in plats.

In 1909 a large number of head selections were made from some of the best varieties. These were sown in head rows and the most promising were saved in 1910 and sown in increase rows. Additional selections were made in 1910 and 1911, partly within the pure lines and partly from the mass varieties. In every case the selections appearing most promising the next year were saved and grown again.

In 1912 various selections were grown in hundredth-acre plats, 8-rod rows, and head rows. The hail that year almost completely destroyed the winter wheat nursery. No yields could be determined though some plants survived the hail. From the records of previous years it was possible to determine which were the most promising selections. Some seed of these was obtained from surviving plants and sown that fall. Most of the selections had then been grown long enough to determine which were the most promising. Since that time most of the effort in the nursery work has been devoted to studying and increasing the selections already made rather than to the making of new ones.

At the present time 9 selections are being grown in replicated plats in comparison with the mass variety, Kharkov, C. I. No. 1583. Milling and baking tests are being conducted to determine their value in comparison with commercial varieties.

SPRING WHEAT

Spring wheat is not as important a crop in Montana as winter wheat. In the Judith Basin the acreage of spring wheat is very small in comparison with that of winter wheat. In the eastern part of the State, where winter wheat is not a sure crop, spring wheat is of more importance.

The work with spring wheat at Moccasin has included field plat and nursery tests. The varieties tested have included those that have given the best results in other dry-land districts of the Great Plains area.

The spring wheat varieties are sown at the rate of 4 pecks to the acre. The date of seeding has been governed by the climatic conditions. The best results are obtained from seeding as early as soil and weather conditions in the spring will permit. This date varies, of course, in different years.

Varietal Tests

The varietal testing of spring wheat was started in 1908 when

20 varieties were grown. They were sown on ground that had been broken in 1907 and the seed bed was not in good tilth when the varieties were sown on May 5. The precipitation for June and July was below normal. As a result of the low precipitation and poor seed bed, low yields were obtained from all varieties.

In 1909 the varieties were sown on well prepared fallow ground. The seeding was not done until May 12. The precipitation that year was above normal and good yields were obtained from all varieties.

In 1910 the varieties were sown April 19. The precipitation was below normal, in fact, the seasonal precipitation for 1910 was the lowest recorded since the substation was established. The yields of all varieties were low, the average for the 23 varieties tested being 11.4 bushels per acre. A surprising fact in this year was that the common spring wheats outyielded the durum varieties. This result was contrary to the prevailing opinion that the durum varieties are more resistant to drought than the common spring wheats. Low yields of durum varieties were obtained at several of the field stations in the Great Plains in 1910.

In 1911, the spring wheat varieties were sown in twentieth-acre plats. This was done because of a shortage of summer-fallowed land. The seeding was done April 20 in a well prepared seed bed. The precipitation in May and June was about normal but there was only 0.5 of an inch of rain in July. This was followed by excessive rainfall in August, which came in time to benefit the spring wheats. The total for the month was 6.31 inches. All varieties produced good yields and the quality of the grain was good.

In 1912 the precipitation for June was nearly two inches below normal. This was accompanied by rather hot weather. The spring wheat varieties were just beginning to head on July 12 when they were completely destroyed by a severe hailstorm. While most varieties made some second growth no grain was produced.

A change was made in the method of testing the spring wheat varieties in 1913. Instead of seeding them in single tenth-acre or twentieth-acre plats they were sown in fiftieth-acre plats and each variety replicated five times. Seeding was done April 21 on well prepared fallow ground. The crop this year was produced under normal conditions.

In 1914 the spring wheat was again grown in replicated fiftieth-acre plats. The seeding was done on April 20. The precipitation in

FIG. 3. Spring wheat test plots. Beloturka, a durum variety, on the right and Marquis on the left.

FIG. 4. Spring wheat identification nursery. Several hundred varieties are grown in short rows and specimens are kept to use in identifying varieties being grown.

May and June was above normal. Hot, dry weather in July and August caused the wheat to ripen early and reduced the yields.

The year 1915 was marked by abnormally high rainfall and low temperature during most of the growing season. The spring wheat was sown in replicate plats on April 9. The yields this year were the highest recorded at the substation.

Summary of Spring Wheat Yields

Table XV gives the annual and average yields of 25 varieties of spring wheat that have been grown in plat tests at the Judith Basin substation during periods of varying length from 1908 to 1915, inclusive.

This table shows that Galgalos, C. I. No. 2398, has produced the highest average yield both for the 4-year period (1908-11) and the 7-year period (1908-11 and 1913-15). This wheat is a soft or semihard variety and is of little value for milling purposes. The next highest yielding variety is a durum wheat, Pelissier, C. I. No. 1584. This variety has a 7-year average yield of 27.2 bushels per acre, which is only 0.4 of a bushel less than the yield of Galgalos.

Leading Varieties of Spring Wheat

Of the 25 varieties of spring wheat that are listed in Table XV only 9 have been grown during the entire period. Of these 5 belong to the durum group, 2 to the Fife group, 1 to the Preston group, and 1 is a miscellaneous variety. Table XVI gives the average dates of seeding, heading, and maturity, the average height and weight per bushel, and the average yields of grain and of straw from each variety during the seven years. From this table it will be seen that, as a group, the durum varieties yield higher than the other groups.

Durum wheat. The leading durum wheat is Pelissier, C. I. No. 1584. This variety has white glumes and black awns. The kernels are large, hard, and a clear amber color. The other durum varieties that have been grown at Moccasin belong to the Kubanka group. They have glabrous yellow glumes and yellow awns.

Common wheat. Among the common wheats that have been tried, the Galgalos, C. I. No. 2398, has produced the highest 7-year average yield. This variety is beardless, with brown pubescent glumes and rather large, soft, white kernels. While it yields well,

Table XV. Annual and average yields of 25 varieties of spring wheat grown in plat tests at the Judith Basin substation, Moccasin, Mont., during periods of varying length in the seven years 1908 to 1911 and 1913 to 1915, inclusive.*

Group and variety	C. I. No.	Yield in bushels per acre									
		1908	1909	1910	1911	1913	1914	1915	Average		
									1908-11	1908-11 1913-15	For period grown
Durum group:											
Arnautka	1493	10.0	36.7	10.0	25.0				20.4		20.4
Do.	1494	10.0	33.0	7.6	31.7				20.6		20.6
Beloturka	1520	9.5	40.3	6.5	29.0	30.0	25.2	40.1	21.3	25.8	25.8
Bledur	1471	7.5	28.3	9.5	29.0				18.6		18.6
Gharnovka	1447	5.0	35.8	10.0	30.0				20.3		20.3
Kubanka	1440	5.0	37.8	8.8	33.0	30.7	23.0	40.7	21.1	25.5	25.5
Pelissier	1584	10.0	41.0	10.5	28.3	32.0	26.5	42.2	22.5	27.2	27.2
Pererodka	1350	5.0	36.7	12.7	36.0	32.0	25.3	40.1	22.6	26.8	26.8
Purple	3024	10.0	39.0	8.5	26.0				20.9		20.9
Taganrog	1570	3.3	36.3	16.3	24.3				20.0		20.0
Velvet Don	1445	7.5	32.3	6.1	26.0				18.0		18.0
Yellow Gharnovka	1444	15.0	39.3	8.2	27.7	32.8	25.0	39.2	22.5	26.8	26.8
Fife group:											
Cole Hybrid (No. 61)	4062		30.3	10.2	31.0	29.7	22.5	30.8			26.9
Ghirka Spring	1517	3.3	34.2	13.2	25.2	29.0	23.0	38.0	19.0	23.7	23.7
Glyndon (Minn. No. 163)	2873				28.0	20.0	22.7	41.0			27.9
Marquis	3641					33.5	23.7	42.3			33.1
Power	3697					28.7	24.1	41.0			31.2
Rysting	3022	2.5	29.0	13.0	27.0	26.7	23.0	40.7	18.0	23.1	23.1
Preston group:											
Fretes	1596	7.5	23.9	16.8	32.7	35.2	25.7	42.5	20.2	26.3	26.3
Preston (Minn. No. 188)	2958		31.0	13.5	25.0	29.2	22.4	41.6			27.1
S. Dak. Climax			29.3	14.6	24.7						22.5
Bluestem group:											
Haynes (Minn. No. 169)	2874		29.7	9.1	18.7						
Haynes (Minn. No. 51)	3021	5.0	30.0	11.7	21.0				17.0		17.0
Miscellaneous:											
Galgalos	2398	7.5	40.2	18.5	31.3	30.7	24.5	40.5	24.4	27.6	27.6

* Crop of 1912 was entirely destroyed by hail.

Table XVI. Average dates of seeding, heading, and maturity, days from seeding to maturity, height, yield of grain and straw, and weight per bushel of 9 leading spring wheat varieties at the Judith Basin substation, Moccasin, Mont., during seven years, 1908-1911 and 1913-1915, inclusive.

Group and variety	C. I. No.	Average date			Days from seeding to maturity	[a]Height	Yield per acre		[b]Weight per bushel
		Seeded	Headed	Ripe			Grain	[a]Straw	
						Inches	Bu.	Lbs.	Lbs.
Durum group:									
Beloturka	1520	April 24	July 16	Aug. 24	122	43.5	25.8	3,108	59.6
Kubanka	1440	do.	July 17	Aug. 26	124	42.5	25.5	3,073	59.6
Pelissier	1584	do.	do.	do.	124	43.0	27.2	2,980	60.0
Pererodka	1350	do.	July 15	Aug. 25	123	42.0	26.8	3,200	59.8
Yellow Gharnovka	1444	do.	July 16	Aug. 26	124	42.6	26.8	3,172	59.8
Fife group:									
Ghirka Spring	1517	do.	July 17	Aug. 25	123	37.5	23.7	2,576	59.0
Rysting	3022	do.	July 20	Aug. 27	125	39.0	23.1	2,796	59.2
Preston group:									
Fretes	1596	do.	July 18	Aug. 25	123	38.0	26.3	3,131	59.4
Miscellaneous:									
Galgalos	2398	do.	July 16	Aug. 26	124	35.5	27.6	2,500	59.6

[a] Average for six years, 1909-1911 and 1913-1915, inclusive.
[b] Average for five years, 1910-1911 and 1913-1915, inclusive.

it is of poor milling quality and for that reason can not be recommended.

Of the fife group, only 2 varieties have been grown during the full period. These are Rysting and Ghirka. The Ghirka ripens about the same time as the durum varieties, while the Rysting is somewhat later. These 2 varieties have yielded from 3 to 4 bushels less than the durum wheats.

Fretes, C. I. No. 1596, is the only variety belonging to the Preston group that has been grown during the seven years. This variety yields a little more than the fife varieties but not quite as much as the durums.

Table XVII gives the annual and average yields of the leading variety in each of the groups for 1913, 1914, and 1915. From this table it will be seen that the Fretes leads, with Pelissier second and Marquis third. The Marquis has been grown at Moccasin for only three years. During that time it has been among the highest yielders and because of its good milling qualities probably is a good variety to grow.

Table XVII. Annual and average yields of the leading variety in each group of spring wheat grown at the Judith Basin substation, Moccasin, Mont., during the three years, 1913-1915, inclusive.

Group and variety	C. I. No.	Yield in bushels per acre			
		1913	1914	1915	Average
Durum group:					
Pelissier	1584	32.0	26.5	42.2	33.6
Fife group:					
Marquis	3641	33.5	23.7	42.3	33.2
Preston group:					
Fretes	1596	35.2	25.7	42.5	34.5
Miscellaneous:					
Galgalos	2398	30.7	24.5	40.5	31.9

Nursery Tests

The nursery work with spring wheat has been conducted along the same general lines as that with winter wheat. The work was

started in 1909, when 206 varieties and selections were grown in 2-rod rows. In 1910 and 1911 head selections were made from the most promising varieties. In 1912 the spring wheat nursery was completely destroyed by hail. A reserve supply of seed of a few of the selections was available and was sown in 1913. At the present time several selections are being tested in fiftieth-acre plats.

COMPARISON OF SPRING AND WINTER WHEATS

Table XVIII gives the annual and average yields of the leading varieties of spring and winter wheats during six years, 1909 to 1911 and 1913 to 1915, inclusive. Since the spring wheat was destroyed by hail in 1912, it was necessary to omit that year. The table shows that on the average the winter wheats outyield the spring varieties by about 8 bushels per acre.

Table XVIII. Annual and average yields of leading varieties of spring and winter wheat grown at the Judith Basin substation, Moccasin, Mont., in the six years, 1909 to 1911, and 1913 to 1915, inclusive.

Group and Variety	C. I. No.	Yield in bushels per acre						
		1909	1910	1911	1913	1914	1915	Average
Winter wheat								
Crimean group:								
Kharkov	1583	32.8	48.0	41.3	31.1	24.5	49.4	38.0
Do.	1442	20.7	46.2	43.3	33.1	25.5	49.0	36.3
Turkey	1558	21.7	43.7	43.7	32.1	25.8	49.2	36.0
Spring wheat								
Durum group:								
Pelissier	1584	41.0	10.5	28.3	32.6	26.5	42.2	30.2
Fife group:								
Ghirka...........	1517	34.2	13.2	25.2	29.0	23.0	38.0	27.1
Preston group:								
Fretes	1596	23.9	16.8	32.7	35.2	25.7	42.5	29.4
Miscellaneous:								
Galgalos	2398	40.2	18.5	31.3	30.7	24.5	40.5	30.9

In 1909, when there was considerable winterkilling of the winter wheats, the spring wheats produced the larger yields. In 1910 and

1911, which were both years of drought, the winter varieties outyielded the spring wheats. In 1913 and 1914 the yields were about equal. In 1915, when the rainfall was abnormally high, the winter wheats yielded 6 to 7 bushels more than the spring varieties. For the six years, the average yield of the best winter wheat was 7.1 bushels higher than that of the best spring wheat. It should be remembered that the yields of winter wheat in 1913, 1914, and 1915, are from acre plats, while those of spring wheat are from replicated fiftieth-acre plats.

The growing of winter wheat is to be recommended in the Judith Basin and generally in Montana wherever it is practicable, because the average yield is higher than that of spring wheat. In a dry year it will yield from 3 to 4 times as much as the spring varieties.

EXPERIMENTS WITH OATS

Next to wheat, oats are the most important cereal crop in Montana. In 1915 the area sown to oats in the State was estimated at 600,000 acres, with an average yield of 52 bushels per acre. Oats are not grown as a cash crop like wheat, but for feeding chiefly. The yields obtained at Moccasin are quite satisfactory and show

FIG. 5. Oat test plots. Kherson on the right and Sixty-Day on the left—two leading dry-land varieties.

that oats usually can be successfully grown on the dry lands of the State.

In the varietal tests at Moccasin the small-kerneled early oats have been sown at the rate of 4 pecks per acre. Seeding tests show but little difference in the results obtained from the 4-peck and 5-peck rate. In dry years, however, the lower rate of seeding gives the better yields. The larger-kerneled varieties are sown at the rate of 5 pecks per acre. In a date-of-seeding test the best results were obtained from seeding as early in the spring as soil and climatic conditions permitted. In all the varietal work the effort has been to seed as early as possible.

VARIETAL TEST OF OATS

Table XIX gives the annual and average yields of 24 varieties of oats grown in plats at the Judith Basin substation from 1908 to 1915. Of the 24 varieties in this table, only 3 have been tested during the entire period and only 14 of them are now being grown.

In 1908 the oats were sown in a poor seed bed. Because of this and the drought in June and July, the yields were low. The year 1909 was one of abnormally high rainfall and good yields were obtained. In 1910 quite severe drought conditions prevailed during the growing season and the yields were low. It is noticeable that in this year the early oats outyielded the late varieties. In 1911 the oats which ripened before the heavy August rains were the only ones to mature a crop. The rainfall during the month was 6.34 inches. This caused the late oats to make a second growth and they were not ripe when the first frost came. No crop was produced in 1912 because of hail. In 1913 and 1914 crops were produced under nearly normal conditions, although in 1914 the dry weather in July reduced the yields somewhat. The only year in the period when the late oats outyielded the early ones was in 1915, when the rainfall for the growing season was 2 inches above normal and the yields obtained were the highest recorded at the station.

In 1908, 1909, 1910, and 1913 the varieties were grown in unreplicated tenth-acre plats and in 1911 and 1912 in unreplicated twentieth-acre plats. In 1914 and 1915 they were grown in fiftieth-acre plats replicated five times.

Table XIX. Annual and average yields of 24 varieties of oats grown in plats at the Judith Basin substation for periods of varying length during the eight years from 1908 to 1915, inclusive.[a]

Group and variety	C. I. No.	Yield in bushels per acre									
									Average		
		1908	1909	1910	1911	1913	1914	1915	1908-11	1913-15	1908-11 1913-15
Early group:											
Early Champion		10.0	67.2	5.7	b				20.7		
Kherson	459	20.5	80.6	32.0	67.5	68.4	59.0	90.0	50.1	72.5	58.3
Sixty-Day	165	20.5	84.4	33.0	71.2	75.3	59.0	93.7	52.0	76.0	62.4
Sixty-Day selection	165-4P4				68.1	78.4	57.2	94.0		76.5	
Sixty-Day	625			29.5	58.7	73.4	56.2	88.4		72.7	
Do.	626				53.7	80.0	56.0	95.6		77.2	
Midseason group:											
Banner	751					73.8	46.3	99.0		73.0	
Canadian	444	5.0	82.6	14.2	b				25.4		
Danish	441	20.0	76.8	23.6	b	56.2	47.3	100.0	30.1	67.8	46.2
Dakota No. 4	753						50.0	99.0			
Early Mountain	754	10.0	68.7	5.8							
Garton White			67.8	18.3	b						
Golden Rain	493			23.4	b						
Lincoln	738						51 0	100.0			
Red Algerian	286	5.5	66.4	15.4	b				21.8		
Red Siberian	487		69.2	11.4	b						
Silvermine	714						49.0	101.0			
Siberian	741					70.0	46.3	98.7		71.7	
Swedish Select	134	15.0	77.0	22.3	b	53.1	50.0	108.0	28.6	70.4	46.5
Victory	742			28.0	b		42.9	97.0			
Late side group:											
Sparrowbill	443	15.0	69.0	20.1	b				26.0		
White Russian	471	5.0	81.0	7.6	b				23.4		
White Tartarian	300	13.3	67.3	18.0	b				24.6		
Yellow Giant	342	15.0	65.0	8.6	b				22.1		

[a] Crop destroyed by hail in 1912.

[b] Made second growth during rainy weather in August and were not ripe when first frost came.

Leading Varieties

The varieties of oats that have been grown at Moccasin may be divided into three groups according to their date of maturity,—early, midseason, and late. At Moccasin the early oats have given the best average results.

Data on average dates of heading and of maturity, height, weight per bushel, and yield of grain and of straw for some of the leading varieties are given in Table XX.

Early Varieties. The Sixty-Day and Kherson varieties are the only early oats that have been tested at Moccasin during the entire seven years.* The Sixty-Day variety was introduced from southwestern Russia into the United States by the U. S. Department of Agriculture in 1901. The Kherson was imported from the same general locality a few years earlier by the Nebraska Agricultural Experiment Station. The two varieties are practically identical. The straw is rather short and fine and the heads loose and spreading. The grain is yellow in color, small, long, and rather slender. The hull is thin and under favorable conditions the weight per bushel is high. In the Judith Basin these varieties reach maturity under ordinary conditions in 95 to 105 days and are about ten days earlier than the midseason varieties. At Moccasin the average yield of the Sixty-Day, which is 62.4 bushels, is slightly larger than that of the Kherson with an average yield of 58.3 bushels. The two pure-line selections from the Sixty-Day have slightly exceeded the parent variety in average yields for the years they have been grown. There is some objection to these oats by farmers because of the yellow color and the small size of the kernel. As oats are commonly grown in Montana for feed, rather than to sell, the yellow color is not objectionable. Because of the thin hulls, these varieties have a larger proportion of kernel to hull than the larger types of oats.

The Sixty-Day is being increased at the Judith Basin substation. About 2,000 bushels have already been distributed throughout the dry-land areas of the State and the results obtained seem to indicate that for these lands the Sixty-Day variety is the best.

Midseason Varieties. Of the varieties of oats that have been tested at Moccasin, 13 can be classed as midseason in maturity.

* For a more extended discussion of these varieties, see Warburton, C. W., Sixty-Day and Kherson oats, U. S. Dept. Agr. Farmers' Bul. 395, pp. 27, fig. 5, 1910.

Table XX. Average dates of seeding, heading, and ripening, days from seeding to maturity, height, weight per bushel, and yield of grain and straw of leading oat varieties at the Judith Basin substation during the seven years, 1908 to 1911 and 1913 to 1915, inclusive.

Group and variety	C. I. No.	Average date			Days from seeding to maturity	[a]Height	Average yield			Weight per bushel
		Sown	Headed	Ripe			Grain		[b]Straw	
							1908-11 1913-15	1913-15		
						Inches	Bu.	Bu.	Lbs.	Lbs.
Early yellow group:										
Sixty-Day	165	April 29	July 6	Aug. 7	100	36.5	62.4	76.0	2,250	[c]34.6
Kherson	459	do.	do.	do.	100	36.3	58.3	72.5	2,274	[c]34.6
Midseason white group:										
Siberian[d]	741	April 21	July 21	Aug. 15	114	48.0		71.7	3,226	36.6
Swedish Select	134	April 29	July 17	Aug. 16	110	42.0	46.5	70.4	2,714	[c]37.0
Danish	441	do.	do.	Aug. 18	111	39.0	46.2	67.8	2,513	[e]32.3

[a] Average for six years, 1909-1911 and 1913-1915, inclusive.
[b] Average for five years, 1909-1910 and 1913-1915, inclusive.
[c] Average for five years, 1910-1911 and 1913-1915, inclusive.
[d] Average for three years, 1913-1915, inclusive.
[e] Average for four years, 1910, and 1913-1915, inclusive.

Swedish Select is the only variety in this group that has been grown in the entire seven years This variety has a 7-year average yield of 46.5 bushels, which is 15.9 bushels lower than the 7-year average yield of Sixty-Day. Other typical varieties of this group are Danish, Lincoln, and Silvermine. All of these are more suitable for growing under irrigation than on the dry farms in Montana.

The varieties of the midseason group have tall, coarse straw and large, rather broad grain. They are from a week to ten days later in maturing than varieties of the early group.

Late Varieties. The late side oats such as White Russian and White Tartarian have not produced good yields at Moccasin except in 1909. In that year they did not yield more than the early and midseason varieties, while in less favorable years such as 1908 and 1910 they were considerably lower in yield. The growing of these late oats was discontinued in 1911. None of them can be recommended for growing on the dry lands in Montana.

EXPERIMENTS WITH BARLEY

Barley is not as important a crop in Montana as wheat and oats. The estimated area sown to barley in the State in 1915 was 80,000 acres, or about 13 per cent of the oat acreage and 6 per cent of the wheat acreage of that year . The results of the experiments at Moccasin show that good yields of barley can be obtained on dry land and that the crop is a profitable one. Barley is grown chiefly for feeding purposes.

The varietal tests at Moccasin have included both the hulled and hull-less varieties. As with the other spring cereals, early seeding has given the best results. The hulled varieties are seeded at the rate of 5 pecks per acre and the hull-less varieties at the rate of 4 pecks.

VARIETAL TEST OF BARLEY

Seven varieties of barley were grown in 1908. Because of the poor seed bed and drought, low yields were obtained. In 1909 fairly good yields were obtained from all varieties. In 1910, 6 more varieties were added to the test. Because of the shortage of summer-fallowed land it was necessary to grow the varieties on the ground used for testing barley in 1909. The land was plowed early in the spring and the seeding was done April 20. The resulting yields were low. In 1911, the hot, dry weather in July reduced the yields.

In 1912 all varieties were destroyed by hail. In 1913 good yields were obtained from all varieties. The hot, dry weather during July, 1914, caused the varieties to ripen early and the quality of the grain was poor that year. The yields obtained in 1915 were the highest recorded at the station.

The barley varieties were grown in unreplicated tenth-acre plats in 1908, 1909, 1910, and 1913, and in unreplicated twentieth-acre plats in 1911 and 1912. In 1914 and 1915 they were grown in fiftieth-acre plats replicated five times.

Table XXI gives the annual and average yields of the barley varieties that have been tested at Moccasin from 1908 to 1915. Of the 19 varieties listed in this table, 9 belong to the 2-rowed hulled group, 5 to the 6-rowed hulled group, 2 to the 2-rowed naked group, and 3 to the 6-rowed naked group. Only 3 of the 19 varieties have been grown in all seven years and only 14 are now being grown.

Table XXII shows that White Smyrna, C. I. No. 195, with a 5-year (1910-11 and 1913-15) average yield of 52.9 bushels, is the leading variety. The White Smyrna is a 2-rowed hulled variety that was obtained from Asia Minor. The head is of medium length and the kernels are large. The straw is rather short, especially in a dry season, and the heads are often only partially pushed out of the sheath.

The White Smyrna is being increased at Moccasin for distribution among the farmers. About 1,200 bushels have been sold. The results obtained in other parts of the State agree with those at Moccasin, indicating that White Smyrna is well adapted to the dry lands of Montana.

Hannchen is a 2-rowed variety, with a narrow, nodding head, that has given good results at Moccasin. It is a selection from Hanna made by the Swedish Plant Breeding Association, of Svalof, Sweden. This variety grows a little taller than White Smyrna and is later in maturing. The average yield of the Hannchen for the five years is about 5 bushels less than that of the White Smyrna.

The leading varieties among the 6-rowed hulled group are Coast and Mariout.

The Coast barley is known also as California Feed and Bay Brewing. It grows taller than the Mariout. The head is not as compact and the grain does not always thresh free from the beard.

Table XXI. Annual and average yields of 19 varieties of barley grown in plat tests on the Judith Basin substation, 1908-1911 and 1913-1915, inclusive.[a]

Group and variety	C. I. No.	Yield in bushels per acre[b]									
		1908	1909	1910	1911	1913	1914	1915	Average		
									1910-11 1913-15	1913-15	1908-11 1913-15
2-rowed hulled group:											
Bohemian	27		48.5	11.2							
Canadian Thorpe	740					50.0	36.0	65.1		50.3	
Franconian	680						31.2	80.0			
Hannchen	531			14.4	45.8	54.3	46.0	78.8	47.9	59.7	
Hanna	678						29.5	78.2			
Mansury	617	20.0	45.7	13.0	38.3	48.7	38.0	70.8	41.8	52.5	37.8
Svanhals	187					48.9	43.5	68.1		53.5	
Thorpe	921	10.0	53.3	11.1	28.3	52.6	39.2	66.7	39.6	52.8	37.4
White Smyrna	195			12.3	52.0	70.0	50.0	80.3	52.9	66.8	
6-rowed hulled group:											
Beldi	190			8.0	43.7	53.7	42.2	73.6	44.2	56.2	
Coast	690			15.0	43.7	55.0	43.1	83.1	48.0	60.4	
Gatami	575			8.2	34.4						
Manchuria	354		45.2	9.8	40.8	39.2	36.0	52.2	35.6	42.5	
Mariout	261			16.2	47.0	47.9	51.3	72.0	46.8	57.1	
2-rowed naked group:											
Clyde	909					37.5	22.0				
McEvans	621	5.5	32.6	10.3	19.3						
6-rowed naked group:											
Black Hull-less	596	10.0	43.8	13.6	25.3						
Himalaya (Guy Mayle)	620	5.5	33.2	12.3	25.0	43.0	30.3	48.8	31.9	40.7	28.2
Nepal (White Hull-less)	595	20.0	42.4	16.4	30.0	37.0	25.7	41.8	30.2	34.8	30.5

[a] Crop destroyed by hail in 1912.
[b] Hulled varieties in bushels of 48 pounds; naked varieties in bushels of 60 pounds.

Table XXII. Average date of seeding, heading, ripening, days from seeding to maturity, height, yield of straw and of grain, and weight per bushel of the leading varieties of barley at the Judith Basin substation, Moccasin, Mont., during five years, 1910, 1911, and 1913-15, inclusive.

Group and variety	C. I. No.	Average date			Days from seeding to maturity	Height	Average yield			Weight per bushel
		Sown	Headed	Ripe			Grain	Grain	Straw	
						Inches	Bu.	Lbs.	Lbs.	Lbs.
2-rowed hulled group:										
White Smyrna	195	April 18	July 6	Aug. 4	108	29	52.9	2,540	1,996	48.2
Hannchen	531	do.	July 11	Aug. 6	110	32	47.9	2,219	2,456	48.4
6-rowed hulled group:										
Coast	690	do.	July 6	Aug. 5	109	32	48.0	2,304	1,195	46.0
Mariout	261	do.	July 5	do.	109	31	46.8	2,248	1,524	46.2
6-rowed naked group:										
Himalaya (Guy Mayle).	620	do.	July 6	do.	109	31	31.9	1,914	1,904	61.0
Nepal (White Hull-less)	595	do.	July 8	do.	109	32.6	30.2	1,812	1,850	61.0

In average yield it has equalled Hannchen but White Smyrna has exceeded it by about 5 bushels.

The Mariout has a compact spike and a rather coarse grain that does not always thresh entirely free from the beard. It matures about the same time as White Smyrna. The average yield of the Mariout is slightly lower than that of the Coast.

The leading naked varieties of barley at Moccasin are Nepal, commonly known as the White Hull-less and Himalaya or Guy Mayle. The 5-year average yield of Himalaya, as shown in Table XXI, is slightly greater than that of Nepal. In the 7-year averages, however, (Table XXI), Nepal exceeds Himalaya by 2.3 bushels. The Nepal is a 6-rowed, naked, hooded variety, sometimes called White Hull-less. The kernels are of medium size and amber in color. The Himalaya is a 6-rowed naked bearded barley, with bluish kernels. Because of the absence of beards the Nepal is commonly grown in preference to the Himalaya. The heads of the Nepal have a tendency to break off when ripe, and the variety also lodges to some extent in wet years. The broad leaves, coarse straw, and absence of beards make this variety a popular one for hay production.

The average yield of the Nepal at Moccasin in the five years was 30.2 bushels, 20 bushels less than that of the White Smyrna during the same period. The weight per bushel of the naked varieties is 60 pounds while that of the hulled varieties is 48 pounds, so that the actual difference in yield is less than would appear from these figures. In pounds, the yield of the Nepal is about one-fourth less than that of White Smyrna.

The average dates of sowing, heading, and ripening, and the average height, yield, and weight per bushel of these 6 varieties for five years (1910, 1911, 1913, 1914, and 1915) are given in Table XXII.

EXPERIMENTS WITH FLAX

Experiments with flax were not started until 1911. Flax is not grown to any great extent in the Judith Basin. The crop is important in the eastern part of the State, although there is not as much flax raised now as there was several years ago. It is usually grown in newly settled districts as it is considered a good crop to grow on sod land.

The experiments at Moccasin have included tests of both seed and fiber flax. Quite a number of fiber varieties were tested in 1911, but as they were of little value for seed production they were discarded.

VARIETAL TEST OF FLAX

Nineteen varieties of flax have been grown in the varietal test. Of these, 12 belong to the European seed, 2 to the Smyrna seed, 4 to the European short fiber, and 2 to the European tall fiber groups. In 1911, 14 varieties were grown in twentieth-acre plats. The land used had been cropped to barley in 1909 and 1910. It was spring plowed in 1911 and the seed bed was in good tilth when the varieties were seeded May 15. The dry weather in July caused the flax to begin to ripen early and the heavy rains in August started a second growth. This made the flax late in maturing and reduced the yields.

In 1912, 17 varieties were grown. These were seeded May 14 in twentieth-acre plats on land that had been cropped to winter wheat the year before. Flax was the only spring grain that produced any seed in 1912, the others being destroyed by hail. The hail came when the flax was in full bloom. While it undoubtedly reduced the yields the plants made a second growth and produced a fairly

FIG. 6. Flax test plots. A Russian importation on the right and a North Dakota selection on the left.

good crop. In 1913 the flax was grown in tenth-acre plats on fallow ground. The yields that year were quite satisfactory. In 1914 and 1915 the flax varieties were grown on fallow ground in replicated fiftieth-acre plats.

The yields in 1914 were reduced by a disease which attacked the young plants. This disease attacks the plant just above the cotyledons and apparently stops its growth until it puts out basal branches below the injured part. The growth is then normal, but the time required to produce these branches makes the plants late in maturing. The seed is produced on these branches, which take the place of the central stem.

The annual and average yields in bushels per acre of the varieties of flax that have been grown in field plats at Moccasin in the five years, 1911 to 1915, are given in Table XXIII.

Leading Varieties

Table XXIII shows that in both the 5-year and 2-year averages the varieties of the European seed flax group yield more than those of the other groups. The 5 highest yielding strains for the 5-year period, C. I. Nos. 19, 3, 2, 16, and 18, all belong to the seed flax

FIG. 7. The Flax nursery. Flax selections are tested in rows before being grown in plats.

Table XXIII. Annual and average yields of 19 varieties of flax grown in plats at the Judith Basin substation, Moccasin, Montana, in periods of varying length from 1911 to 1915, inclusive.

Group and variety	C. I. No.	Yield in bushels per acre						
		1911	1912	1913	1914	1915	Average	
							1911-15	1914-15
European seed:								
Russian (N. Dak. No. 155)	19	19.3	13.3	16.6	13.0	22.8	17.0	17.9
Russian (N. Dak. No. 155)	17	14.6	11.7	15.6	12.5	18.9	14.7	15.6
Select Russian (N. Dak. No. 608)	1	17.1	10.0	14.0	12.0	19.3	14.5	15.8
Select Russian (N. Dak. No. 609)	45				13.6	19.0		16.3
Select Russian (N. Dak. No. 1215)	3	15.7	13.0	18.0	12.8	19.5	15.8	16.2
Montana Common	6	15.4	10.0	9.0	13.2	20.0	13.5	16.6
Select Riga (N. Dak. No. 1214)	2	18.3	9.0	19.6	13.0	19.1	15.8	16.1
Stepan (N. Dak. No. 1340)	5	15.0	11.3	16.8	12.1	19.9	15.0	16.0
N. Dak. Resistant No. 52	8	16.0	6.3	14.0	11.8	19.5	13.7	15.7
N. Dak. No. 1221	16	15.7	12.7	16.4	13.2	19.9	15.6	16.5
Fargo Common (N. Dak. No. 1133)	18	14.6	10.1	19.2	13.2	19.5	15.4	16.4
Smyrna seed:								
Smyrna	30				14.8	19.2		17.0
Turkish	7	6.9	4.8	12.0	9.0	15.1	9.5	12.0
European short fiber:								
Kazan (N. Dak. No. 1326)	4	9.2	10.0	17.5	13.2	18.9	13.7	16.0
Idaho Common	15				13.0	19.4		16.2
N. Dak. Resistant No. 114	13				12.3	16.8		14.6
Primost (Minn. No. 25)	12	11.0	10.3	17.5	12.8	19.1	14.1	16.0
European tall fiber:								
Blue Blossom	22	9.6	8.3	15.3	12.1	17.5	10.5	14.6
Pskov	32				10.0	8.0		9.0

group. Russian, C. I. No. 19 (N. Dak No. 155), is the highest yielder and Select Russian, C. I. No. 3 (N. Dak. No. 1213), a selection from North Dakota No. 155, is second. C. I. Nos. 17 and 19 are both Russian, North Dakota No. 155, but were received at Moccasin from different sources. C. I. No. 19 has given better results than C. I. No. 17. North Dakota No. 155 is a bulk lot of seed of Russian flax obtained by the North Dakota Agricultural Experiment Station in 1898. It has been grown and distributed by them since that time. C. I. Nos. 1, 3, and 45 are selections from this variety developed in the nursery at the North Dakota station.

C. I. Nos. 2 and 16 were both developed through selection from common flax varieties at the North Dakota station, while C. I. No. 18 was a bulk lot of seed obtained by that station in 1901 from a seed house at Fargo, N. Dak. All of these strains are of the Russian seed type of flax and with the exception of some variations in coarseness of stem and earliness are much alike.

North Dakota Resistant No. 52, a wilt resistant flax of the seed type, has not yielded as well as the Russian.

The Smyrna flax, C. I. No. 30, which ranks second in average yield for the two years it has been grown, was imported from Smyrna, Turkey, by the United States Department of Agriculture, in 1913. This variety has shorter straw and more numerous basal branches than the European seed flaxes. From results obtained elsewhere it seems to be better able to withstand unfavorable hot, dry weather than other varieties in the test.

North Dakota Resistant No. 114 and Primost (Minn. No. 25), both of which belong to the short fiber group, did not produce yields which compare favorably with those of the European seed flaxes. These varieties would probably give proportionately better results in regions where flax diseases are more serious than at Moccasin.

The tall fiber type of flax is of no value for seed production in Montana.

Table XXIV gives the average dates of seeding, heading, and ripening, the yields of straw and grain, and the weight per bushel of the 5 leading varieties of flax in the years, 1911 to 1915, inclusive.

Nursery Tests

Nursery work with flax was not started until 1914, when 50

Table XXIV. Average dates of seeding, heading and ripening, days from seeding to maturity, yield of grain and straw and weight per bushel of leading flax varieties at the Judith Basin substation, Moccasin, Mont., in the five years, 1911-1915, inclusive.

Group and variety	C. I. No.	Average date			Days from seeding to maturity	Height	Average yield per acre		[a]Weight per bushel
		Seeded	Headed	Ripe			Grain	Straw	
European seed flax:						Inches	Bu.	Lbs.	Lbs.
(N. Dak. No. 155) Russian	19	May 8	July 19	Aug. 28	112	23.0	17.0	1,654	56.0
Select Russian N. Dak. No. 1215	3	do.	July 20	do.	112	23.0	15.8	1,610	56.0
Select Riga N. Dak. No. 1214	2	do.	do.	do.	112	22.8	15.8	1,456	55.7
N. Dak. No. 1221	16	do.	do.	do.	112	22.6	15.6	1,440	55.7
Fargo Common N. Dak. No. 1133	18	do.	do.	do.	112	22.0	15.4	1,386	55.7

[a] Average for four years, 1912-1915.

varieties and strains were tested. These varieties were grown in fiftieth-acre and hundredth-acre plats and in 8-rod rows. Most of them were recent importations from Europe which were grown in this country for the first time in 1914.

In 1915 the flax nursery was increased. In addition to the tests in fiftieth-acre plats and 8-rod rows, 204 selections were grown in head rows. Some of the head rows were selections from the most promising varieties and some were selections from a natural hybrid.

Several promising varieties which are now being grown in the nursery will soon be added to the varietal test.

Date-of-Seeding Test

There seems to be some question as to the proper date on which to sow flax. The impression seems to exist in some sections that flax should be sown later than the other spring grains. The date-of-seeding test at Moccasin has not been conducted long enough to justify drawing definite conclusions from it. The results seem to indicate, however, that early seeding is the best. In 1915 the highest yield was obtained from the plat seeded April 9. While there was some freezing weather after this date it apparently did no harm to the flax. The tests at Moccasin show that flax should be sown not later than May 1, as seedings made after that date will not produce as good yields as earlier ones.

Rate-of-Seeding Test

A rate-of-seeding test with flax is being conducted at Moccasin, but like the date-of-seeding test, it has not been continued long enough to justify any definite conclusions. During the last three years the varietal test plats have been seeded at the rate of 18 pounds per acre. Very satisfactory stands and yields have been obtained from this rate, although the rate test seems to indicate that a little heavier seeding would give better results.

COMPARISON OF LEADING VARIETIES OF CEREALS

Table XXV gives the annual and average yields in pounds per acre of the leading varieties of each of the cereals at Moccasin for five years, 1910-1911 and 1913 to 1915, inclusive. This table is given so that a comparison may be made of the actual yield of grain of each of the cereals. It will be seen from this table that

Table XXV. Annual and average yields and average farm value of the leading variety of each of the cereals grown on the Judith Basin substation, Moccasin, Mont., for five years 1910, 1911, and 1913-1915, inclusive.

Crop and Variety	C. I. No.	Yield in pounds per acre						Value of crop per acre
		1910	1911	1913	1914	1915	Average	
Kharkov winter wheat.....	1583	2,880	2,478	1,866	1,470	2,964	2,331	$31.08
Pelissier spring wheat.....	1584	630	1,698	1,920	1,590	2,530	1,673	21.58
Sixty-Day oat	165	1,056	2,278	2,400	1,888	2,908	2,126	23.70
White Smyrna barley......	195	590	2,490	3,360	2,400	3,854	2,540	28.42
Nepal barley	595	984	1,800	2,220	1,542	2,508	1,810	18.24
Russian flax	19		1,070	930	728	1,282	1,002	[a]27.09

[a] Average for four years, 1911 and 1913-1915.

on the average White Smyrna barley produces more grain per acre than any of the other cereals. Kharkov winter wheat is second and Sixty-Day oats is third in production of grain.

The average farm value per acre of each of the crops is also given in Table XXV. To obtain this value the annual yield of each crop was multiplied by the farm price per bushel in Montana, on December 1 of that year, and the annual values for the five years were then averaged. Winter wheat leads in value per acre, with White Smyrna barley second and flax third.

EXPERIMENTS WITH MINOR CEREALS

Twenty-seven varieties of proso millet have been tested at Moccasin at some time during the past eight years. While most of the varieties tried will mature seed in a favorable year, the yield is small and in some years no seed is produced. For this reason the crop is not recommended for the Judith Basin.

Some early varieties of brown kaoliang and broomcorn were tried for three years. Owing to the short season and cool nights none of them matured seed.

Emmer and spelt have also been tried; but are not as promising as some of the other grain crops.

Demonstration Farm Tests

Between the years 1905 and 1914 dry-land demonstration farm tests were carried on by the Experiment Station at thirteen different places in the State. The object of these tests was to find out the yields and to demonstrate the possibilities of some of the dry farm crops in the different localities. The demonstration tracts were from ½ to 3 acres in area of each plot, and the work was carried on under the conditions of a general dry farm. The counties in which work was conducted and from which the data here given are taken were: Custer, Dawson, Rosebud, Valley, Blaine, Yellowstone, Musselshell, Meagher, Lewis and Clark, Cascade, and Teton. A detailed report of this work up to 1911 is given in Experiment Station Bulletins Nos. 74 and 83 and Circular 3.

WINTER WHEAT

The Turkey Red variety of winter wheat was used in all of the demonstration tests. The average yield of this variety in 47

tests on the demonstration farms between 1907 and 1913 was 25.6 bushels per acre.

SPRING WHEAT

While several varieties of spring wheat were grown on the demonstration farms the one variety which was used on all farms during all of the years was the Kubanka, a macaroni wheat. The average yield of this variety in 36 tests was 17.8 bushels per acre.

OATS

The Sixty-Day variety of oats was used at all of the farms during all of these years. In 44 tests between 1906 and 1913 the average yield was 35.3 bushels per acre.

BARLEY

Nepal or White Hull-less was the variety most generally used in the demonstration farm tests. The average yield in 33 tests was 15.6 bushels per acre. The Himalaya or Guy Mayle variety averaged 16.1 bushels in 10 demonstration farm tests.

Summary

Cooperative experiments with cereals at the Judith Basin substation, Moccasin, Mont., have been conducted during eight years, 1908 to 1915, inclusive.

The Judith Basin substation is located in the west central part of Fergus County, in central Montana. The altitude is 4,300 feet.

The yields obtained at Moccasin will not be representative of all the dry-land area, but the comparative results obtained are believed to be applicable in general to all the dry-farming area of Montana.

The annual average precipitation at Moccasin for eighteen years, 1898-1915, inclusive, is 16.66 inches. The average seasonal rainfall (April to July, inclusive) for the same years is 9.41 inches.

The soil at Moccasin on which the cereal varieties have been tested is a dark clay loam of limestone origin.

On the average, satisfactory yields are obtained from winter and spring wheat, spring oats, barley and flax.

The best winter wheats are Kharkov and Turkey. These belong to the Crimean group of hard winter wheats.

The best rate to sow winter wheat is 3 pecks per acre. The

best date to sow is from August 10 to September 10.

The highest yields of spring wheats have been obtained from varieties of durum wheat. Of these the Pelissier has been the best. Of the common spring wheats the best variety to grow appears to be Marquis.

Spring wheats are seeded at the rate of 4 pecks per acre.

Best results are obtained from sowing all spring wheat, oats and barley as early in the spring as soil and climatic conditions will permit.

The highest average yield of oats was obtained from the Sixty-Day. This variety averaged about 16 bushels per acre more than later maturing varieties.

The best rate of seeding for the small-kerneled early varieties of oats such as Sixty-Day is about 4 pecks per acre.

White Smyrna barley, a 2-rowed hulled variety, has given the highest average yield.

The hulled varieties of barley are seeded at the rate of 5 pecks and the naked varieties at the rate of 4 pecks per acre.

The highest yield of flax in a 5-year test was obtained from the Russian variety.

It is probable that best results will be obtained if flax is seeded early, between April 15 and May 1. The best rate seems to be from 20 to 25 pounds per acre.

In pounds per acre, the average yield of White Smyrna barley is greater than that of the best variety of any of the other cereal crops. Kharkov winter wheat is second in yield, followed by Sixty-Day oats, Nepal hull-less barley, Pelissier spring wheat, and Russian flax.

In the value per acre based on the farm price December 1 ot each year, Kharkov winter wheat leads, followed by White Smyrna barley, Russian flax, Sixty-Day oats, Pelissier durum spring wheat, and Nepal hull-less barley.

Emmer and spelt do not give as good yields as barley and oats.

Proso millet has been tried, but is not a promising crop.

Early varieties of brown kaoliang and broomcorn have been tested, but do not mature seed.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION
BOZEMAN, MONTANA

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Profits in Farming on Irrigated Areas
in the
Gallatin Valley, Montana

BY
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Farm Management

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

NOTICE.—The Bulletins of the Experiment Station will be mailed free to any citizen of Montana on request. Please state whether all the publications are desired as issued or only those specified. Give name and address plainly. All communications to the Experiment Station should be addressed to

THE MONTANA EXPERIMENT STATION.
Bozeman, Montana

Contents

Profits in Farming on Irrigated Areas in the Gallatin Valley, Montana

INTRODUCTION

"Farm management" has been defined as the science which treats of the organization and administration of a farm business so as to give the largest continuous profit.

For a number of years a great deal of information has been at hand on subjects pertaining to plant and animal production, but it has only been within very recent times that attention has been given to the matter of fitting crop and stock enterprises together into a definite unit that would return the maximum in profit to the farmer.

OBJECT OF FARM MANAGEMENT SURVEY

It was soon recognized that little progress could be made in this direction until careful and complete study had been made of large numbers of farms under different systems of management. It was necessary to find out the normal relationship between the different elements of a farm business. Variations from this normal could then be studied and their effect upon the profits of the farm noted.

Out of the need for information on these subjects has grown a method of study known as the farm survey.

In this method of study it is assumed that the agriculture of any well developed farming community has passed through a process of evolution, and that the practices best adapted to the region are the ones that have finally prevailed on the most profitable farms while others have been discontinued.

The object of surveys is to find these more profitable farms and by careful study determine in what respects they differ from other farms in the region that have been less successful; in other words, to determine the factors that make for successful farm operation in the region under study.

HISTORY OF FARM MANAGEMENT SURVEYS

The first farm management survey was conducted by Cornell University in 1908 under the direction of Dr. G. F. Warren and reported in bulletin No. 295 of that Experiment Station. So valuable were the results obtained that the use of this method of study spread rapidly until at the present time farm surveys have been made or are under way in nearly every State of the Union. Some of our most valuable agricultural information we owe to the farm survey.

HOW FARM MANAGEMENT SURVEYS ARE MADE

An area is selected where the agriculture is well developed and where conditions affecting the several farms are as uniform as possible. Each farm in this area is visited and the operator asked to give information from which may be calculated the returns from the farm for the year under study. The data are transferred to a record sheet where they are checked very carefully in order to locate any discrepancies or omissions. After the records from a region have all been brought together they are checked by another person, so that it becomes exceedingly difficult for any error to get through that would seriously affect the conclusions to be drawn from the work. The records are then analyzed carefully and the factors determined that have had a bearing upon the labor income.

ACCURACY OF FARM MANAGEMENT SURVEY RECORDS

Comparatively few farmers keep a record of their business transactions. Most of them keep memoranda of one kind or another, but in most cases they are incomplete and unsatisfactory. For this reason it has been charged that the average farmer does not know enough about his business to enable him to give information from which conclusions of value can be drawn. After taking farm business records from a large number of farmers in different States, we feel convinced that the farmer really knows more about the details of his business than he is usually given credit for. If asked how much money he made from his entire farm during the preceding year, he usually has very little idea. However, if asked how much he received from any specific crop or class of stock or how much he paid for labor or binding twine, he can usually tell at once. He has the details of his business fairly well in hand but does not know

how to summarize these details so as to permit him to consider the business of his farm as a whole.

These details, when brought together by survey methods and checked carefully, give us results in which the element of error is present to no greater extent than is the case in most other lines of research.

THE GALLATIN VALLEY SURVEY

One hundred and eighty-six records were secured on farms in the Gallatin Valley during the summer of 1914.* They represent a record of the business on these farms for the fiscal year beginning April 1, 1913, and ending April 1, 1914. The farmers were found particularly courteous in almost every case and glad to help with the work.

DESCRIPTION OF THE REGION

The Gallatin Valley is located in Gallatin County, Montana. It comprises an area of very fertile land about twenty miles in width and about twice that in length. This area is surrounded on three sides by mountains—the Gallatin range on the south and the Bridger range on the north and east. The valley has an average elevation of about 4,500 feet. Numerous streams which have their origin in the adjacent mountains traverse the valley, furnishing good drainage and an abundant supply of water for irrigation.

The soils of this area consist generally of a rather heavy, silty loam ranging in color from light brown to almost black. They are particularly well adapted for the growth of small grains such as wheat, oats, barley, and peas. Record yields of some of these crops have been obtained in this region. The lower lands are well adapted for the growth of grass and hay crops. Here we find stock-raising developed to a greater degree than is the case on the benches where forage crops do not do as well.

The average annual precipitation of the Gallatin Valley is between 19 and 20 inches a year, according to the records of the Government weather bureau station at Bozeman. The larger part of this rainfall comes during the spring and fall months.

*Acknowledgment is due Lynn C. Robertson and F. Josiah Chase, who assisted in collecting the data presented in this bulletin.

The climate of the valley is characterized by warm, clear days and cool nights in summer and by clear, cold weather in winter. The last killing frost usually occurs during the latter part of May and the first killing frost early in September. This gives an average growing period of from 90 to 100 days. The climate on the whole is pleasant and conducive to good health and good spirits.

HISTORY OF AGRICULTURAL DEVELOPMENT

Agriculture in the Gallatin Valley began in a small way as early as 1860. Many of those who were disappointed in their search for gold found wealth in the rich, virgin soil, their farm products commanding high prices in the mining districts to the west. For many years the valley lacked outside communication except by slow and costly wagon trains. With the coming of the Northern Pacific Railway in 1884 a new era in agriculture made secure by the introduction of irrigation was inaugurated. Since then the development of the region has been rapid. At the present time the valley is traversed by the main line of the Northern Pacific and by two branch lines of the Chicago, Milwaukee and St. Paul railways. Towns and shipping points have sprung up along these roads so that opportunities for outside communication and for marketing the staple crops are excellent.

The majority of farms in this region are served by the rural free mail delivery and the rural telephone. These in addition to a system of well kept public highways make the region easily and quickly accessible.

SEASONAL FACTORS RELATED TO RESULTS OF THIS SURVEY

Rainfall.—Reference to the weather records of the station at Bozeman* indicates that the precipitation for the year 1913 was slightly less than the average for the ten-year period preceding; however, this rainfall appears to have been somewhat more evenly distributed throughout the growing season than is often the case. Its effectiveness was probably at least normal.

Temperature.—Examination of the weather record shows that on July 14, 1913, there was a minimum temperature of 32°. This resulted in a frost which did more or less damage to crops of all

*Mont. Exp. Sta. Bul. 99.

kinds. This was an unusual occurrence in this valley. The records show that such a thing had not happened for over thirty years. The damage done by this frost was probably overestimated at the time, as indicated by the crop yields for that year as shown in Table XII. The pea crop was probably damaged to as great an extent as any, and yet seed men who are contracting peas in this valley are of the opinion that a yield of 21.4 bushels as shown by our records is probably not greatly below the average normal yield for the region. A factor that compensated somewhat for the occurrence of this frost in July was the fact that the first killing frost of that year did not occur until September 27, which was some three weeks later than the average date of the first killing frost for the ten-year period preceding. This permitted crops to escape frost in the fall, some of which are caught in the normal year. In any case, while the average labor income for the region may be slightly below normal, it will have no appreciable effect upon any of the conclusions to be drawn from this work.

PRICES RECEIVED FOR STAPLE FARM PRODUCTS DURING THE SURVEY YEAR

Reference to Table I shows that prices received by farmers for grain crops during the survey year were somewhat lower than is the case at the present time. Wheat is a conspicuous example, where the price was as low as 64 cents per bushel.

TABLE I. PRICES RECEIVED BY FARMERS IN THIS REGION FOR STAPLE CROPS DURING THE SURVEY YEAR

Crop	Price received
Wheat	$0.64 per bu.
Oats	1.01 per cwt.
Barley	1.04 per cwt.
Peas	1.75 per bu.
Clover or alfalfa, loose	6.50 per T.
Clover or alfalfa, baled	8.00 per T.
Timothy, loose	7.60 per T.
Timothy, baled	10.00 per T.

Our records do not show the price received by farmers in this region for animal products during the survey year. They show

only the total amount received from such sources; however, Table II, prepared from data obtained from the 1915 Yearbook of the U. S. Department of Agriculture, gives the range of prices at important markets of some of the leading agricultural products, including animal products, for the years 1913 and 1915.

It will be seen from this table that the prices of most grain products have increased somewhat during the two-year period, while the prices of animal products have in most cases remained about the same or increased slightly. It is thought that these changes in relative price of farm products are not sufficient to cause any of the factors discussed in the following pages to have a different bearing upon labor incomes than was the case during the survey year.

TABLE II. PRICES ON THE CHICAGO MARKET FOR IMPORTANT AGRICULTURAL PRODUCTS FOR THE YEARS 1913 AND 1915. (1915 YEARBOOK U. S. DEPARTMENT OF AGRICULTURE.)

Product	1913			1915		
*Wheat	$ .89½	—	$ .93	$1.06	—	$1.28½
†Oats	.37⅝	—	.40⅛	.40⅞	—	.44
‡Barley	.50	—	.79	.62	—	.77
Timothy	13.00	—	19.50	12.00	—	21.00
Butter	.24	—	.36	.24	—	.34
Eggs	.16	—	.37	.16	—	.38
Hogs	6.95	—	9.62	5.80	—	8.95
Cattle	3.00	—	10.25	4.00	—	13.60

*Cash price per bushel, No. 1 northern spring, December.
†Cash price per bushel, December.
‡Cash price per bushel, December.

DEFINITION OF TERMS USED IN THIS REPORT

Since some of the terms used in subsequent pages are more or less technical in character, it may help in the understanding of the material presented if they are defined at this point.

Operator's labor income represents what the farmer has left after paying all farm expenses and setting aside an amount sufficient to pay 6 per cent interest on the capital invested. This, in addition to the use of a dwelling and to such products as the farm furnishes toward the family living, represents what the farmer actually receives for his labor.

Farm labor income.—Where farms are operated by tenants it often happens that the operator receives a good labor income, but the landlord receives such a low return on his investment that the farm as a whole is a poorly paying business. In such a case the operator's labor income has no relation to the efficiency in organization and management. In order to avoid this difficulty, in all tabulations in this report, unless otherwise specified, farm labor income has been used rather than operator's labor income. The farm labor income is found by adding operator's and landlord's receipts and from the total deducting the sum of the operator's and landlord's expenses and interest on their combined capital. Regardless of the type of tenure, farm labor income may be considered as a fairly accurate measure of efficiency in organization and management.

Working capital refers to money invested in the different forms of farm investment other than real estate. It represents the portion of the total capital that is reserved for equipping and carrying on the work of the farm.

Diversity index represents the number of major enterprises on a farm or the equivalent in minor enterprises. If, for example, a farm has a diversity index of 4, it means that the farm has four enterprises that contribute substantially to the income. The diversity index is found as follows: Find the sum of the magnitudes of all enterprises (in most cases the receipts from an enterprise may be taken as its magnitude), divide the magnitude of each enterprise by the sum of all, square each of the quotients, and divide unity by the sum of these squares. The result is the diversity index.

Crop index represents the crop yields on any farm as compared with the average yields for the region. The crop index is determined as follows: Divide the total yield of each crop on the farm by the average yield for the region. Add the quotients and divide by the total acreage of these crops. Multiply the quotient by 100. The result is the crop index. A crop index of 125 on any farm indicates that on that farm the crop yields are 25 per cent better than the average of the region. If the crop index is 85 it indicates that the yields are 15 per cent below the average of the region.

Animal unit.—As an approximate measure of the amount of stock on any farm the term "animal unit" has been adopted. An animal unit is an amount of stock of any kind sufficient to eat as

much feed and produce as much manure as a mature cow or horse. Thus one cow, bull, or steer two years old or older may be called an animal unit. Two head of colts or young cattle may be counted as one. Seven sheep, 14 lambs, 5 hogs, 10 pigs, 100 hens, may each be called an animal unit.

A farm with the following livestock inventory has 32.2 animal units:

	Animal unit
8 horses	8.
2 colts	1.
10 cows	10.
8 young cattle	4.
3 hogs	.6
15 pigs	1.5
30 sheep	4.3
25 lambs	1.8
100 hens	1.
Total	32.2

Productive animal units refers to productive animals only. It includes all farm animals except work animals.

Man equivalent represents the average number of men working on a farm throughout the year. It is determined as follows: Find the approximate number of months of man labor on a farm and divide by 12. (The operator's time is counted as 12 months.) The result is the man equivalent or the average number of men working.

THE FARM PROFIT

DISTRIBUTION OF LABOR INCOMES ON FARMS IN THIS REGION

Figure 1 shows the labor incomes made on farms in this region. It will be noted that about one farmer out of three receives nothing or less than nothing for his labor. Two out of three receive a labor income. Of those receiving a labor income, one farmer in two makes over $1000, one in seven makes over $2000, and one in sixteen makes over $3000. Of those farmers failing to receive a labor income, about one in five loses over $1000, and one in thirty loses over $2000. The average labor income on farms in this region is $555 as shown in Table XI.

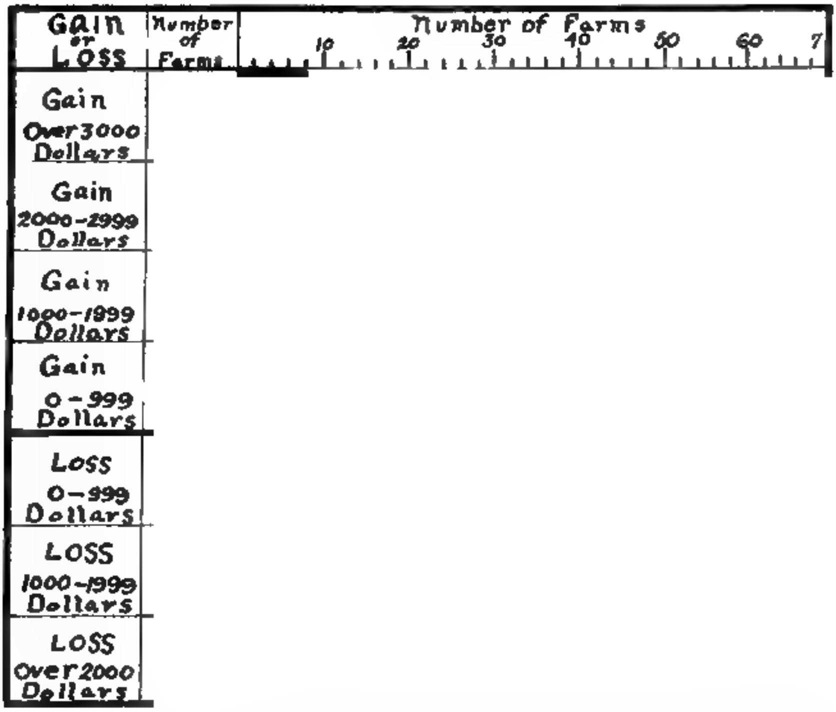


FIG 1. This figure shows graphically the distribution of labor incomes on farms in this region. Farms shown as having a loss have a minus labor income; those with a gain have a plus labor income.

These data indicate that while the average farmer is receiving little more than hired man's wages for his labor, there is abundant opportunity for making a very satisfactory labor income, as shown by the fact that one-third of the farmers are making at least a thousand dollars.

The achievement of farmers in this region not only shows up well when compared with farms in other States but, I believe, compares favorably with incomes realized in other lines of endeavor. A recent investigation by the Federal Trade Commission as reported by Mr. Stanley A. Dennis in "System" (January, 1916) discloses the fact that of the 250,000 business corporations in the United States, 190,000 make less than $5000 a year, while over 100,000, or 40 per cent, make nothing. "There is a general economic law which applies to all industries in which there is free competition,

according to which the net income from the industry is, on the average, just sufficient to pay interest on the capital invested and wages to the labor employed. This law applies only under conditions of free competition. * * * It must not be inferred that this law operates with equal efficiency at all times. Due to various causes, there will be fluctuations in the profit of any industry, and at times the profits may be larger or smaller than merely sufficient to pay interest and wages."† Such conditions, however, are only temporary and in themselves set to work forces which ultimately bring the income back to the normal level. Farm surveys that have been made in different parts of the country at different times indicate that this law operates very freely in the case of the farming industry. From Table III it will be noted that the average farmer in nearly every case received in addition to interest on his investment an amount sufficient to pay him farm wages for his labor.

The fact that one farmer out of every ten in this region is making a labor income of at least $2000 while the average farmer is receiving only hired man's wages for his labor, justifies us in making considerable effort to find out how the successful farms differ from those that are unsuccessful. These factors will be discussed in the following pages.

TABLE III. LABOR INCOMES ON FARMS OPERATED BY OWNERS IN DIFFERENT STATES

Year	Location	Number of farms	Labor Income
1907	Tompkins County, N. Y.	615	$423
1909	Townships in southern New Hampshire	266	337
1913	Utah Lake Valley, Utah	69	417
1910	Representative areas in Ind., Ill., Ia.	273	408
1912	Johnson County, Mo.	272	314
1913	Brooke County, W. Va.	158	45
1913	Gallatin Valley, Mont.	112	*474

*This labor income is for farms operated by owners. The average given on page 20 is for all farms included in the survey.

†Spillman, W. J. In Proceedings First National Conference on Marketing and Farm Credits, p. 110.

CAPITAL

AMOUNT AND DISTRIBUTION OF CAPITAL

From Table IV it will be seen that the modern farm business is one that requires the investment of considerable capital. The largest item of investment is that of real estate, which, on the average farm, constitutes 85.5 per cent of the total outlay.

TABLE IV. AMOUNT AND DISTRIBUTION OF CAPITAL ON FARMS IN THE SURVEY

Items of investment	Amount invested	Per cent of total investment
Machinery	$817	3.0
Livestock	2,521	9.3
Feed and supplies	296	1.1
Cash	287	1.1
Real estate	23,252	85.5
Total	$27,173	100.0

AMOUNT OF CAPITAL RELATED TO LABOR INCOMES

From Table V it will be noted that the amount of capital invested has a direct relation to the labor income from farms in this region. Farms with an investment of less than $30,000 show a labor income below the average for the region. As the amount of capital increases the labor income increases, so that farms with an investment of over $40,000 have an average labor income of over $750. The amount of capital invested has a direct relation to the size of business on farms, a factor which will be taken up at some length later in the discussion.

TABLE V. AMOUNT OF CAPITAL RELATED TO LABOR INCOMES

Amount of capital	Number of farms	Average capital	Labor income
$0–19,999	66	$14,375	$496
20,000–29,999	56	24,839	522
30,000–39,999	35	34,505	555
Over 40,000	29	51,955	750

Average capital, $27,173.

DISTRIBUTION OF CAPITAL RELATED TO LABOR INCOMES

Another factor that has considerable bearing on farm profits in this region is the distribution of capital between different items of investment. On the average farm 85.5 per cent of the total capital is tied up in real estate, allowing only 14.5 per cent for equipping and carrying on the work of the farm. That this is an improper distribution of the capital is shown in Table VI. It will be seen from this table that as the amount of working capital increases from one-tenth of the total capital to one-fifth, the labor income steadily increases from $312 to $972. The anticipation of a rise in land values has caused many farmers to secure a much larger amount of land than they can adequately equip with machinery and livestock. In many cases they have assumed a heavy mortgage indebtedness and any surplus money that can be gathered together is used in paying off a part of this mortgage rather than in adding to the equipment of the farm. If the speculative feature could be entirely removed from the agriculture of this region, it would make for a much more healthy and substantial farm development. After careful study of Table VI it seems safe to say that if we were to double the amount of equipment in the shape of machinery and livestock on farms in this region, it would at least double the labor income.

TABLE VI. RELATION OF THE PERCENTAGE OF WORKING CAPITAL TO LABOR INCOMES

Percentage of total capital represented by working capital	Number of farms	Per cent working capital	Labor income
Over 20 per cent	34	26.0	$972
15–19 per cent	49	17.3	692
10–14 per cent	65	13.1	375
Less than 10 per cent	38	8.6	312

Average working capital, 14.5 per cent.

PRICE PER ACRE OF LAND RELATED TO LABOR INCOMES

From Table VII it appears that land at $100 per acre is cheaper when measured by the standard of earnings than is land at $75 per acre. The person with limited capital very commonly chooses cheap land in order to secure a larger acreage. Our data indicate that he would be much better off were he to choose the higher priced land and smaller acreage. The demand for the cheaper farms has

caused the price to rise to a point that is beyond what such farms are really worth. The highest priced farms in the region also appear to furnish a smaller labor income than the farms of moderate price. Many of these farms are near town and the price represents a speculative value in addition to the real value. This compels the farm business to carry a burden of interest that makes it difficult for the farm to earn a satisfactory labor income. Land that is worth an even hundred dollars per acre appears to be the best investment when it comes to the matter of making a farm profit in this region.

TABLE VII. RELATION OF LAND VALUES TO LABOR INCOME

Price of land per acre	Number of farms	Average price per acre	Labor income
Less than $75	34	$56	$445
75–99	49	83	565
100	53	100	720
Over 100	50	136	388

Average price per acre, $97.16.

FARM RECEIPTS AND EXPENSES

DISTRIBUTION OF FARM RECEIPTS

Table VIII shows the distribution of receipts on farms in this region. It will be noted that the average total receipts per farm amount to $3,767. Of these receipts $2,595, or over two-thirds, is derived from the sale of cash crops, the important crops being wheat, oats, barley, peas, and hay.

Livestock receipts on the average farm constitute only slightly more than one-fourth of the total receipts. The most important livestock enterprises are beef cattle, hogs, dairy cattle, and horses. Sheep and poultry are minor stock enterprises. Most of the farms in this region have two or three important crop enterprises, many in addition have one or more important stock enterprises. Some, however, have but one or two crop enterprises and no stock enterprises of importance.

TABLE VIII. DISTRIBUTION OF FARM RECEIPTS

Items of receipts	Amount
Crops:	
Wheat	$447
Oats	632
Barley	430
Peas	614
Hay	456
Miscellaneous crops	16
Total crop receipts	$2,595
Stock:	
Cattle	$260
Dairy products	196
Hogs	199
Poultry	57
Horses	175
Sheep and wool	80
Bees	2
Total stock receipts	$969
Crop-and-stock receipts	$3,564
Miscellaneous receipts (outside labor, etc.)	70
Increase inventory (other than stock)	133
Total receipts	$3,767

NUMBER OF SOURCES OF INCOME RELATED TO LABOR INCOMES

That the number of sources of income on the farm has a bearing on the labor income is shown in Table IX. The farm with few important sources of income finds itself at a serious disadvantage, particularly in the matter of labor utilization and the use of feed products that would otherwise be wasted. It is only by the com-

TABLE IX. RELATION OF DIVERSITY TO LABOR INCOME

Diversity index	Number of farms	Average diversity index	Average area (acres)	Labor income
Less than 3	88	2.1	249	$531
3–4	48	3.5	289	539
Over 4	50	4.6	252	624

bination of different crops that a program may be laid out that will utilize labor satisfactorily during the summer season. Livestock enterprises, in addition to utilizing a considerable amount of labor at a time of year when it could not be otherwise employed, consume a good deal of product that could not be converted into an income in any other way. The opportunity for making a satisfactory labor income is increased by having two or more crop enterprises and at least one important livestock enterprise.

DISTRIBUTION OF FARM EXPENSES

Table X shows the distribution of farm expenses on farms in this region. It will be seen that labor is the most important item, constituting 42.6 per cent of the total expense. Other large items in the order of their importance are threshing, taxes and insurance, improvements and new equipment. These three items constitute 58.4 per cent of the remaining expense. The total expense per farm in this region is $1,582. The expense per acre is $6.10.

TABLE X. DISTRIBUTION OF FARM EXPENSES

Item of expense	Amount	Per cent of total
Paid labor and board	$561	35.4
Family labor	112	7.2
Improvements and new equipment	181	11.4
Repairs (machinery, buildings, etc.)	66	4.3
Feed	83	5.2
Horseshoeing	11	.7
Veterinary fees	9	.5
Breeding fees	15	.9
Seed	52	3.3
Binding twine	34	2.1
Threshing	234	14.8
Hay pressing	36	2.3
Taxes and insurance	182	11.5
Miscellaneous	6	.4
Total	$1,582	100.0

FINANCIAL SUMMARY

Table XI shows the average capital, total receipts, total expenses, and the farm income. The interest on the average capital at 6 per

cent amounts to $1,630. This, when deducted from the farm income, gives a labor income of $555. This figure represents what the average farm in this region earns after allowing 6 per cent interest on the invested capital.

TABLE XI. FINANCIAL SUMMARY FOR FARMS IN THIS REGION

Capital		$27,173
Total receipts	$3,767	
Total expenses	1,582	
Farm income		2,185
Interest on capital at 6%		1,630
Labor income		555

SYSTEMS OF FARMING

CROPS

The crops shown in Table XII are all grown and marketed in the usual manner with the exception of the pea crop. In the case of this crop the seed is furnished and the crop contracted for in advance by the seed companies. The seed pea industry was introduced into the valley only a few years ago. Since its introduction, however, the industry has grown so rapidly that at present it is second only to oats in importance as a cash crop, as will be noted from Table XIII.

As mentioned previously the yield per acre of crops as shown in Table XII is probably a little below the normal yield for the region.

TABLE XII. ACREAGE AND YIELD PER ACRE OF IMPORTANT CROPS

Crop	Acreage per farm	Yield per acre
Wheat	23	33.9 bu.
Oats	41	56.5 bu.
Barley	21.7	46.5 bu.
Peas	22	21.4 bu.
Hay	59	2.3 T.

Disposal of Crops

Table XIII shows the value per farm of each of the most important crops raised and the value of the amount sold. It will be noted that the average farm sells a little over three-fourths of

the value of the crop raised. The remainder represents the amount that is saved for feed and seed.

All of the important crops of this region are grown as cash crops. In the case of oats and hay a larger percentage of the crop is used for feed than is true of the others, but even of these crops more than one-half is sold.

TABLE XIII. VALUE OF CROP RAISED AND CROP SOLD PER FARM

Crop	Value per farm	Sales per farm	Per cent of crop sold
Wheat	$513	$427	83.2
Oats	944	678	71.8
Barley	524	431	82.2
Peas	635	630	99.2
Hay	845	463	54.8
Total	$3,461	$2,629	75.9

Disposal of Crops Related to Labor Incomes

Table XIV shows that there is an important relation between the percentage of the crop sold and the labor income in this region. Farms selling a high percentage of their crop made a much larger labor income than did those that sold a smaller percentage. A labor income of $1,356 was made on thirty-two farms that sold an average of 93.1 per cent of the value of their crop. Thirty farms that sold only 48.6 per cent of their crop made a labor income of $47. These figures point strongly to the conclusion that under present conditions those who feed any considerable proportion of their marketable crop to animals receive a much smaller labor income than do those who sell a greater part of their crop. The price of grain has risen so much more rapidly in the last few years

TABLE XIV. CROP DISPOSAL RELATED TO LABOR INCOMES

Per cent of total value of crop sold	Number of farms	Average per cent sold	Labor income
Over 90	32	93.1	$1,356
80–89	46	84.1	651
70–79	44	74.2	389
60–69	22	65.7	343
Less than 60	30	48.6	47

than has the price of meat products that it has become necessary to raise animals more and more on cheap feeds and by-products of the farm that are not up to market requirements. As it happens farms in this valley produce a considerable amount of such products and so are able to carry a goodly amount of stock at moderate cost. That these cheap feeds be utilized is essential to the success of the farm business. This point will be discussed at some length in succeeding pages.

Table XIV points overwhelmingly to the necessity of farms in this region having a large amount of crop to be sold as a cash crop.

Labor Incomes on Farms with Different Crops as Major Cash Crops

In Table XV farms have been selected that receive the larger part of their income from one particular crop. It will be noted that thirty-nine farms with peas as a major cash crop had an average labor income of $855. Forty-four oat farms had an average labor income of $688.

Peas and oats appear to be the most profitable crops in this region. The experience of farmers seems to bear out this conclusion as attested by the fact that these crops are being grown as cash crops more extensively than others. The poorest paying crops appear to be barley and hay, barley probably because of its relatively low yield as compared with oats and only a slight advantage in price. The profit in hay is small, the result of a large production and the fact that it is a bulky product and cannot be shipped as cheaply as can other crops. The price of hay is controlled to a much greater extent by local market conditions than is the case with most other crops. The fact that hay is continually being grown in an amount

TABLE XV. LABOR INCOMES WITH DIFFERENT CROPS AS MAJOR CASH CROPS

Major cash crop	Number of farms	Average per cent of total crop sales	Labor income
Peas	39	66.6	$855
Oats	44	66.6	688
Wheat	24	59.6	529
Barley	29	54.2	397
Hay	27	71.3	349

very close to the point of overproduction keeps the price at a low figure in this region.

Relation of Crop Yields to Labor Incomes

The Gallatin Valley being primarily a grain-growing region, we would naturally expect that crop yields would have an important bearing on farm profits. Table XVI shows that this is one of the most important factors controlling farm profits in this region. It will be observed that twenty-five farms with crops almost a third better than the average of the region have an average labor income of $1,731, while eighty-one farms with crops a little over a third poorer than the average of the region have an average labor income of $20. Other groups of farms in the tabulation show a corresponding variation in labor incomes owing to this factor. The importance of this point cannot be overemphasized.

The data point conclusively to the fact that quality of crop production is one of the most important factors influencing the profits from farming in this region.

TABLE XVI. THE RELATION OF CROP INDEX TO LABOR INCOME

Crop index	Number of farms	Average crop index	Labor incomes
Over 120	25	132	$1,731
100–119	26	109	1,137
80–99	54	90	531
Less than 80	81	64	20

Relation of Percentage of Tillable Area in Crop to Labor Income

Table XVII shows the effect of the percentage of tillable area in crop on the labor income. Most of the tillable area not in crop is in summer fallow and a small amount is in tillable pasture. It will be seen from this table that one hundred and four farms with more than four-fifths of their tillable area in crop and with less than three acres per farm in summer fallow had a labor income of over $700. Twenty-five farms with less than 60 per cent of their tillable area in crop and with over 66 acres per farm in summer fallow had a labor income of minus $6. This means that these farms, after paying expenses, lacked $6 of being able to pay interest on the investment and gave the operator nothing whatever for his labor. A

TABLE XVII. RELATION OF THE PERCENTAGE OF TILLABLE AREA IN CROP TO LABOR INCOME

Per cent of tillable area in crop	Number of farms	Average per cent tillable in crop	Acres of summer fallow	Labor income
90–100	68	96.2	.0	$700
80–89	36	84.8	2.6	776
70–79	36	75.4	21.0	660
60–69	21	65.0	53.0	191
Less than 60	25	52.6	66.1	–6

factor that should be mentioned in this connection is a difference in size between farms with a high percentage in crop and those with a low percentage. Table XXIX shows that small farms have a much higher percentage of their tillable area in crop than is the case with large or moderately large farms. Farms shown in Table XVII with a low percentage of their tillable area in crop, in spite of a more favorable size show a labor income considerably below those with a higher percentage in crop and a less favorable size. It goes without saying that land valued at $100 per acre must be kept on full time every year if the operator is to receive a profit from its use.

Weed control.—Soils in the Gallatin Valley are so remarkably fertile that a lack of available plant food is seldom a limiting factor in crop production. In all probability weeds are a more frequent cause of low yields than is any other agency. No intertilled crop of importance is grown in this region, consequently weeds such as wild oats, mustard, fanweed, etc., are very troublesome.

The two most common methods of weed control are rotation with a sod crop and the summer fallow. The former practice is strongly recommended. It is thought that it will take care of the weed situation if care is exercised in planting clean seed. The summer fallow is a practice that we believe will have to be discontinued if a satisfactory income is to be derived from the land. Land that is worth in the neighborhood of one hundred dollars an acre must be made to produce a crop each year. Any portion of the farm that is not producing a crop places a heavy burden of interest and other costs on the farm business, thereby making it very difficult to achieve success.

LIVESTOCK

Amount of Stock on Gallatin Valley Farms

Table XVIII shows the number of head of each class of stock on the average farm in this region. The most conspicuous thing about this table is the small amount of stock of all classes.

As shown by Table XIX the average farm has 30 acres per productive animal unit. Without doubt this amount of stock is insufficient to take care of waste products such as damaged hay and grain, pea straw, and other by-products of the farm which return no income unless utilized in this way. It is safe to say that every farm should have enough stock to fully utilize all such by-products. Such a program, if put into effect, would no doubt increase substantially the amount of stock produced in this region.

TABLE XVIII. NUMBER OF HEAD OF EACH CLASS OF STOCK PER FARM IN THIS REGION

Class of stock	Number per farm
Cows	7.2
Calves and yearlings	7.5
Bulls and steers	1.5
Horses and mules	9.2
Colts	2.1
Swine	8.6
Sheep	18.1
Chickens	79.3

Amount of Stock Related to Labor Incomes

From Table XIX it is shown clearly that the average farm in this region should be more heavily stocked than is the case at present. On forty-three farms with a productive animal unit for each 10 acres

TABLE XIX. AMOUNT OF STOCK RELATED TO LABOR INCOMES

Acres per productive animal unit	Number of farms	Average acres per productive animal unit	Labor income
Less than 10	43	6.1	$999
10–19	33	14.4	647
20–29	38	24.1	593
30–39	24	35.1	290
Over 40	47	77.6	211

Average acres per productive animal unit, 30.

or less there was a labor income of practically $1000. As the amount of stock decreases the labor income corespondingly decreases until farms with 40 acres per productive animal unit show a labor income of only $211.

It must be borne in mind that the farms with a productive animal unit for every 6.1 acres are not heavily stocked. In all probability this amount of stock could be kept on the average farm and fed very largely on cheap products. Farms in the Gallatin Valley have a particularly large amount of by-products that may be utilized as feed for stock. To begin with, most farms have certain areas that cannot be tilled because of the presence of rocks, seepage, or other causes. Such areas produce an excellent growth of grass which may be utilized to the best advantage as pasture. Another feed that farmers are beginning to value highly is pea straw. Many cases have come to the writer's attention where young animals were carried through the winter on this feed and came out in the spring in very good flesh. In regions where hay is stacked out in the open, as it is in this valley, there is always a good deal of the crop damaged more or less by the weather. This damaged hay, while of no market value, may be well utilized by young animals in roughing them through the winter. Animals so fed do not gain much in flesh but grow in frame, so that when placed on grass the following season they increase in weight very rapidly.

In addition to the above-named feeds there is liable to be a considerable amount of crop left in the field after harvest, which animals can pick up readily. A small flock of sheep will find feed from this source on almost any farm from harvest time until snowfall, thereby converting a useless by-product into a substantial source of income.

Crop and Stock Ratio Related to Labor Incomes

Table XX shows that farms with somewhat less than a third of their crop-and-stock receipts from stock have a decidedly better income than those with either a higher or lower percentage from this source.

It might be mentioned here that the conclusions to be drawn from Table XX are in accord with the general result of surveys in other States as far as this point is concerned. The conclusion to be drawn from this table is also well supported by the data presented

in Table XIV which shows that it is imperative as far as profits are concerned that a large percentage of all crops that are marketable be sold as cash crops.

At first thought the results of Tables XIX and XX may appear contradictory, but a little analysis shows that such is not the case. It must be remembered that the most heavily stocked group of farms in Table XIX has only a moderate amount of stock. Such an amount could be easily kept on the average farm and yet permit a large percentage of the crop to be placed on the market as a cash crop. Farm No. 84, described on page 48, furnishes a concrete example of how this thing works out in practice. In spite of selling 91 per cent of the value of all crops raised this farm has a net receipt from stock representing 26 per cent of the total crop-and-stock receipts. Incidentally, this farm has a labor income of $1,413, the highest of any farm in the survey.

A proper conception of the real function of livestock on the farm does not appear to be very generally held. While some farmers stock their farms so heavily as to make it necessary to grow their animals to a considerable extent on high priced feeds, others allow the cheap feeds and by-products of the farm to go entirely to waste because of a lack of animals to utilize them. It would seem the part of wisdom to stock heavily enough to utilize all by-products and cheap feeds but not so heavily as to require animals to be fed to any great extent on marketable stuff that has a high value.

We cannot but feel that with the present high price of grain the main purpose of livestock on the farms in this region is to utilize by-products that would otherwise be wasted and turn them into a source of income. Data presented in Tables XIV, XIX, and XX fully bear out this statement. As mentioned before, this program if

TABLE XX. RELATION OF THE PERCENTAGE OF CROP-AND-STOCK RECEIPTS FROM STOCK TO LABOR INCOMES

Per cent of crop-and-stock receipts from stock	Number of farms	Average per cent from stock	Labor income
Less than 12.5	52	6.8	$429
12.5–24	54	18.3	431
25–37.5	31	30.6	974
37.5–49	25	43.2	514
Over 50	24	72.3	601

put into effect would increase substantially the amount of livestock in this region.

Quality of Livestock Production Related to Labor Incomes

In addition to an amount of livestock sufficient to utilize all of the farm by-products, another factor that seems to be of considerable importance is the quality of livestock production, represented by the net receipts per productive animal unit.

Table XXI shows that a satisfactory labor income is attained only on farms that show a receipt of at least $50 per productive animal unit of stock. There is little profit, much less satisfaction, in feeding even cheap feed to animals of inferior quality. In some cases such animals fail to pay for the feed they eat, to say nothing of making payment for the labor that is expended on them.

TABLE XXI. RELATION OF RECEIPTS PER PRODUCTIVE ANIMAL UNIT TO LABOR INCOMES

Receipts per productive animal unit	Number of farms	Average receipt per productive animal unit	Labor income
Less than $40	25	$32.20	$273
40–49	23	45.00	384
50–69	41	59.10	719
70–89	28	79.10	697
Over 90	32	122.70	667

Probably the two most important causes of low quality of livestock production are livestock losses and a failure of females to produce a sufficient increase. The following tables are compiled from data collected by Dr. Howard Welch of this station on one hundred and fifteen farms in the Gallatin Valley for the year beginning April 1, 1914, and ending April 1, 1915. They are presented here because it is thought that they are of particular interest in connection with this survey.

Livestock Losses in the Gallatin Valley

It will be noted from Table XXII that the loss of mature animals is little more than half that of young animals. According to these figures with ordinary methods of care we may expect a loss of 10 per cent on cattle and horses less than two years old. With mature animals the loss will be a little over half as much. Mature hogs show a very light loss, only 1.5 per cent, while pigs show the

heaviest loss of all, almost a third of them dying before reaching maturity. In Table XXIII is shown the cause of loss with animals of each class and age.

The greatest single cause of loss in the case of mature cattle was bloat. Over half the total number of deaths were from this cause alone.

In the case of calves and yearlings, scours, indigestion, and bloat claimed 44.1 per cent of those that died while blackleg took a toll of 16.7 per cent.

More mature horses died from colic and indigestion than from other causes. Over one-fifth of the total number that died were taken in this manner.

Navel infection was found to be the most frequent cause of death in the case of colts, claiming 27.8 per cent of the total number that died.

More sows died while giving birth to pigs than from any other cause. Even at that there was a loss of only 6 from this cause out of 1,401 animals. Hogs appear to be particularly free from disease in this region.

Our records show the percentage of loss in pigs to be much greater than in any other class of farm animals. As will be noted from the table a large percentage of these animals die because they are not provided with adequate shelter or given proper care.

It will be noted that with animals of all classes a large part of this annual loss could be prevented by the exercise of ordinary care. I believe we may safely assume that with proper shelter and more attention to the matter of feeding, this loss could be reduced at least one-half. Results of a similar investigation in the Bitter Root

TABLE XXII. LOSSES OF LIVESTOCK OF DIFFERENT CLASSES AND AT DIFFERENT AGES

Class of stock	Number of animals	Number died during year	Per cent of loss
Mature cattle	1,386	77	5.5
Calves and yearlings	1,259	120	9.5
Horses	1,132	74	6.5
Colts	478	54	11.3
Hogs	1,401	21	1.5
Pigs	3,223	1,016	31.5

TABLE XXIII. CAUSE OF LOSS WITH ANIMALS OF EACH CLASS AND AGE

(A) **Mature cattle** Cause of death	Number died	Per cent of total loss	(B) **Calves and yearlings** Cause of death	Number died	Per cent of total loss
Bloat	39	50.6	Scours and indigestion	33	27.5
Accident (ditches, straw stacks, etc.)	10	13.0	Bloat	20	16.6
Tuberculosis	8	10.4	Blackleg	20	16.6
Miscellaneous	5	6.5	At birth (exposure, weakness, abortion)	22	18.4
Unknown causes	5	6.5	Accident	10	8.4
Milk fever	4	5.2	Miscellaneous	10	8.3
Old age	3	3.9	Unknown causes	5	4.2
Calving	3	3.9			
Total	77	100.0	Total	120	100.0
(C) **Horses**			(D) **Colts**		
Colic and indigestion	15	20.2	At birth (weakness, exposure, abortion, etc.)	19	35.2
Accident (lightning, cast in ditch, straw stacks, etc.)	13	17.6	Navel-ill	15	27.8
Miscellaneous (influenza, azoturia, impaction, etc.)	16	21.7	Miscellaneous (distemper, sclerostomes, pneumonia, etc.)	10	18.5
Sclerostomes	9	12.1	Accident	8	14.8
Old age	4	5.5	Colic and indigestion	2	3.7
Pneumonia	3	4.0			
Foaling	3	4.1			
Unknown causes	11	14.8			
Total	74	100.0	Total	54	100.0
(E) **Hogs**			(F) **Pigs**		
Farowing	6	28.6	Exposure	460	45.3
Accident	2	9.5	Unknown causes, partly exposure	523	51.4
Miscellaneous	8	38.1	Hairless	24	2.4
Unknown causes	5	23.8	Miscellaneous	9	.9
Total	21	100.0	Total	1,016	100.0

Valley, where more information was obtained relative to the preventability of loss, bear us out in this statement.

When we realize that quality of livestock production has such an important bearing on farm profits, it brings home the necessity of keeping our percentage of stock loss as low as possible as this factor is probably more closely associated with quality of livestock production than any other.

Breeding Records for Livestock in the Gallatin Valley

Another factor that has a close relationship to quality of livestock production is the number of females of each class that bear young each year.

It will be noted from Table XXIV that the breeding record of cows is high, 94.7 per cent of the total number bred bearing young alive. The breeding performance of sows also appears to be very good in this region. The records show 6.5 living pigs for each sow bred. Mares show a poor record with regard both to the percentage conceiving and the percentage bearing living foals. The data show that only 55.9 per cent of the mares bred bear their young alive.

The figures on livestock loss and breeding performance give us an idea of what we may expect as far as these factors are concerned on the average farm with ordinary methods of livestock management. If more attention were given to details of management it could not help but improve the quality of livestock production and increase the profits to be derived from farming in this region.

TABLE XXIV. BREEDING RECORDS FOR ANIMALS OF DIFFERENT CLASSES

	Cows	Mares	Sows
Number bred	631	460	390
Number conceiving	619	316	378
Per cent conceiving	98.1	68.7	96.9
Young born alive	598	257	2,553
Young born dead	21	59	
Per cent of pregnant females bearing young alive	96.6	81.3	
Per cent of females bred bearing young alive	94.7	55.9	
Living pigs per sow bred			6.5
Living pigs per sow conceiving			6.7

SIZE OF FARM BUSINESS

There are various units by which the size of a farm business may be measured. Some of these are total area, crop area, amount of stock, amount of farm expense, amount of farm labor, amount of farm capital, etc. None of these units when used alone is entirely satisfactory; however, by using a combination of two or more a fairly accurate means of measurement may be secured. For the purposes of this study we have used total area and the amount of labor, represented by man equivalent, as a measure of the size of business.

Table XXV shows the relation of man equivalent, or the number of men working on the farm throughout the year, to labor income. It will be noted that the 2-man farm has a distinct advantage over those employing either a greater or a less amount of labor. When we pause to give the matter thought, this is exactly what we would expect. There are many farm operations at all seasons of the year where one man working alone is at a serious disadvantage. No doubt all of us have observed cases where labor was being used inefficiently because of this. Examples could be cited without number. Many of us have observed the poorly spent efforts of men attempting to haul hay from field to barn or stack without help. Before the hay is properly placed upon the wagon a large amount of time is lost in climbing upon the wagon to properly distribute the load. Again, much time is lost in a similar manner before the load is taken care of in barn or stack. On the whole, one man working alone accomplishes only about a third as much as would be accomplished by two men working together. There is little opportunity of getting full and complete service from labor unless there are two men to work together when occasion requires it. If

TABLE XXV. RELATION OF MAN EQUIVALENT TO LABOR INCOME

Man equivalent	Average number of men	Number of farms	Total acres	Labor income
Less than 1.25	1.1	38	124	$508
1.25–1.75	1.5	68	216	598
1.76–2.25	2.0	39	300	748
2.26–2.75	2.4	21	329	367
Over 2.75	3.6	21	472	314

more than two men are employed throughout the year, it becomes difficult to supervise and direct their work so that all do full duty. The class of farm labor available in this region requires pretty careful supervision. As the number of men increases, this becomes a matter of increasing difficulty.

TOTAL AREA RELATED TO LABOR INCOMES

Table XXVI shows the effect of total area upon labor incomes and agrees very closely with the conclusions to be drawn from Table XXV. It will be seen from this table that as the size of farm increases the labor income gradually increases until at an average area of 328 acres it has risen to $938. A further increase in size, including all farms of over 400 acres, brings the labor income down to $297, the lowest point of all. That size of business is one of the most important factors affecting profits in this region cannot be questioned. The importance of this point has been proved time and again in investigations that have been made in this State and in other States.

TABLE XXVI. RELATION OF TOTAL AREA TO LABOR INCOME

Total acreage	Number of farms	Average acreage	Labor income
Less than 140	32	93	$447
141–200	52	167	460
201–280	33	240	558
281–399	40	328	938
Over 400	29	540	297

DISTRIBUTION OF LABOR INCOMES ON FARMS OF DIFFERENT SIZES

Figure 2 shows the distribution of labor incomes on farms of different sizes. The thing that is perhaps most noticeable in this diagram is the greater variation in labor incomes as farms increase in size. There appears to be little opportunity on the small farm either to make a large profit or to suffer a large loss. This is exactly what we would expect with any small business. Take a small grocery store, for example, with a small stock of goods and relatively small sales. With such a business it would be an utter impossibility to realize either a large gain or a large loss because of the small amount of

money involved. As the size of the business increases, opportunity is given for a large gain as well as a large loss. Of farms with less than 140 acres there are none that show a labor income of over $2000 and none that show a loss of as much as $1000. As the size increases, oportunities for gain as well as for loss increase. On farms of over 400 acres one farmer out of every seven makes over $2,500 while one out of nine loses at least $1,500. It appears that farms in this region where ordinary methods of farming are

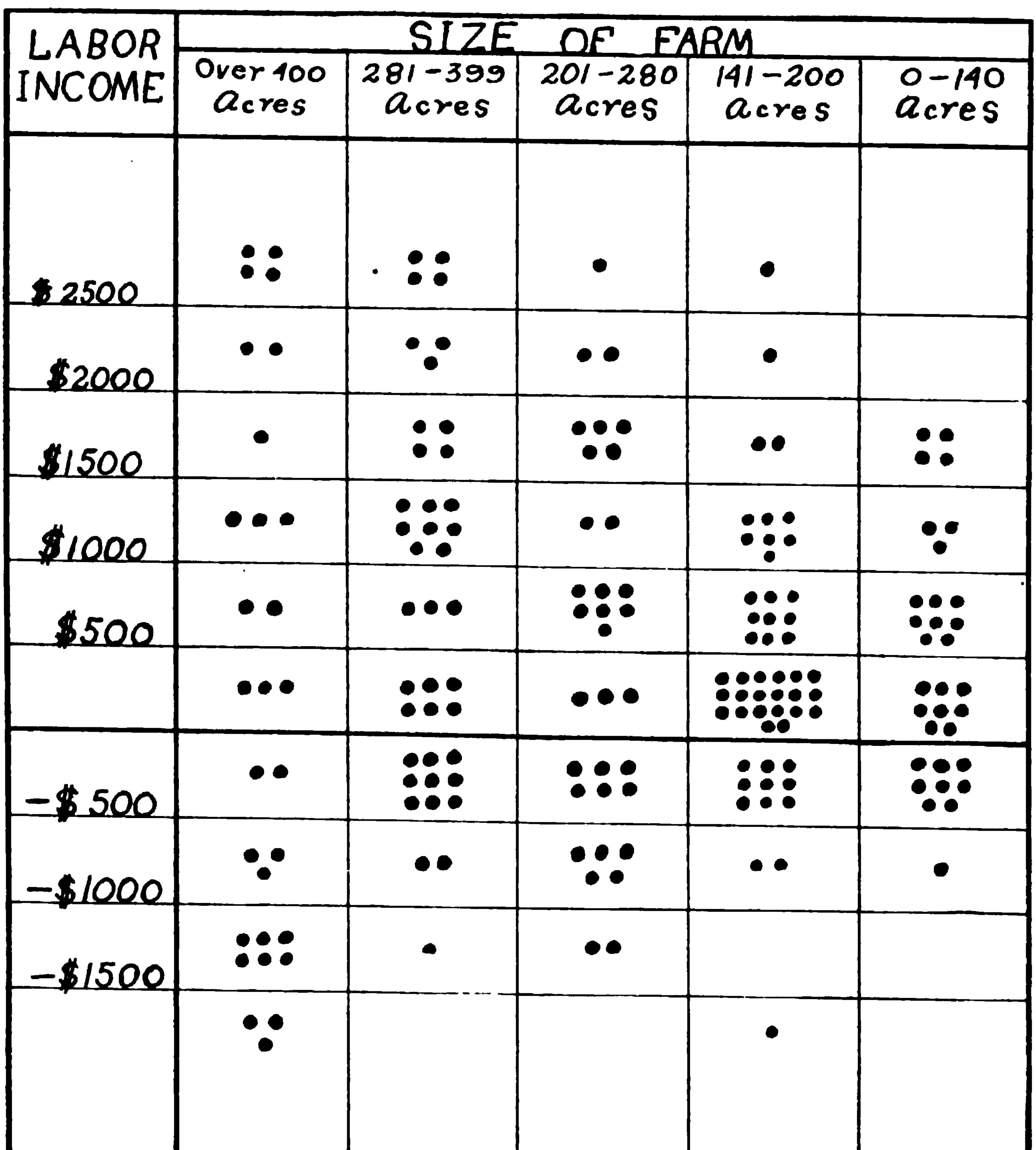


FIG. 2. In the above diagram each dot represents the labor income on a farm. The distribution of dots shows the distribution of labor incomes on farms of different sizes.

followed should contain at least 200 acres in order to give opportunity for making a satisfactory income. With farms of over 400 acres there is a chance for large gains but also a considerable chance for loss. The average farmer in this region will do best to choose the moderately large unit rather than either the very large or the small one. There are a number of reasons why the moderately large farm ordinarily pays best. These will be referred to in subsequent pages of this report.

DISTRIBUTION OF CAPITAL ON FARMS OF DIFFERENT SIZES

In Table XXVII are shown the total capital and the distribution of capital on farms of different sizes. The thing to be particularly noted is that as the size of farm increases a relatively low percentage of the capital is reserved as working capital and a high percentage is tied up in real estate. In all probability neither the largest nor the smallest farms are as well equipped as are the moderately large farms. An investment of $442 for machinery on the smallest farms will not provide an adequate equipment of labor-saving machines. It goes without saying that every farm to be operated efficiently should be able to avail itself of the use of all labor-saving machines that are adaptable to the given type of farming. Cooperative ownership of machinery is a possibility on small farms but it does not appear to be made use of to any great extent in actual practice.

TABLE XXVII. DISTRIBUTION OF CAPITAL ON FARMS OF DIFFERENT SIZES

	Acres 0–140	Acres 141–200	Acres 201–280	Acres 281–399	Acres Over 400
Average size	93	167	240	328	540
Total capital	13,304	19,547	25,640	34,524	47,789
Machinery: Value	442	731	920	904	1,178
Per cent of total	3.3	3.7	3.6	2.6	2.4
Livestock: Value	1,581	2,005	2,532	2,826	4,053
Per cent of total	11.9	10.2	9.9	8.2	8.5
Supplies: Value	220	206	322	333	466
Per cent of total	1.6	1.1	1.3	1.0	1.0
Cash: Value	176	228	270	327	476
Per cent of total	1.4	1.2	1.0	.9	1.0
Real estate: Value	10,885	16,377	21,596	30,134	41,616
Per cent of total	81.8	83.8	84.2	87.3	87.1

SIZE OF FARM RELATED TO EFFICIENCY IN FARM ORGANIZATION

Table XXVIII shows some differences in farm organization between farms of different sizes that should be given consideration at this time. It will be noted that the groups shown in this table do not differ greatly except in one or two particulars. The most noticeable difference is perhaps in crop yields. Even in this respect the variation is not great until we reach the farms of over 400 acres. Here we find a sharp decline in crop yields as shown by a crop index of only 78. This crop yield when considered in connection with the efficiency factors shown in Table XXIX would indicate that farmers in this group were undertaking to handle a greater acreage of crop than they could give proper attention to. The same thing is indicated in Table XXIX under the heading "Efficiency in the use of land."

Farmers on the larger farms would no doubt be much better off, as far as making a profit from their farm business is concerned, were they to dispose of some of their land and devote the money so obtained to increasing their equipment and farming their land a little more intensively.

It will be noted further from Table XXVIII that the large farms are very lightly stocked, the data showing 50 acres of land for each productive animal unit. This amount of stock is inadequate to take

TABLE XXVIII. SIZE OF FARM RELATED TO EFFICIENCY IN FARM ORGANIZATION

	Acres 0–140	Acres 141–200	Acres 201–280	Acres 281–399	Acres Over 400
Average size	93	167	240	328	540
Per cent of crop-and-stock receipts from stock	39.7	32.5	26.0	20.0	25.5
Crop index	87	91.8	86.0	87.8	78.0
Per cent of value of crops sold	73.6	72.5	73.9	80.9	72.9
Acres per productive animal unit	8.9	20.9	20.7	29.0	53.1
Receipts per productive animal unit	81.60	70.64	63.12	64.14	68.70
Diversity index	2.7	3.4	3.2	3.3	3.0
Receipts per acre	21.73	16.55	15.31	14.89	11.18
Expenses per acre	8.25	6.88	6.62	5.65	5.16

care of waste products that could be used for feed. With the exception of the smallest group, all sizes show a strong tendency towards understocking. The small farms also appear to have a little the advantage in quality of livestock production, showing a receipt per productive animal unit somewhat higher than is the case with other groups.

It will be noted that the income per acre as shown by the difference between receipts per acre and expenses per acre is greatest on the small farms and decreases as the farms increase in size. However, the increase in acreage makes the income per farm much larger on the moderately large farm than on the small one. Income per farm or per farmer is, of course, much more important under our conditions than is income per acre.

SIZF OF FARM RELATED TO EFFICIENCY IN USE OF LAND, LABOR AND EQUIPMENT

Reference to Table XXIX indicates that the larger farms have a distinct advantage over the small ones when it comes to the matter of efficiency in the use of labor. Leaving the group of farms of over 400 acres in area out of the discussion for the present because of the fact that they are low in crop yield, it will be seen that the larger farms get almost a third more acres of crop per $100 worth of labor than do the small ones without any decrease in crop yields. The same relation holds in the case of horse-labor, a work-horse handling about a third larger area of crop on the moderately large

TABLE XXIX. RELATION OF SIZE OF FARM TO EFFICIENCY IN THE USE OF LAND LABOR AND EQUIPMENT

	Acres 0–140	Acres 141–200	Acres 201–280	Acres 281–399	Acres Over 400
Average size	93	167	240	328	540
Crop acres per work horse	16.4	20.5	22.0	25.4	34.8
Crop acres per $100 man-labor	13.6	17.1	17.0	19.6	22.5
Crop acres per $100 machinery	19.7	20.7	22.0	32.9	39.4
Investment per acre in buildings	22.74	12.45	8.85	7.76	6.00
Efficiency in use of land:					
1. per cent of tillable area in crop	88.2	81.8	80.7	78.2	72.2
2. Acres in summer fallow	1.9	6.5	16.6	25.1	60.2

farm than on the small one. When we stop to consider the fact that horse-labor usually costs in the neighborhood of ten or twelve cents an hour, we realize the importance of requiring every horse to serve to its utmost capacity. The advantage of the large farm in the use of machinery is even more pronounced than in the case of man and horse-labor. On the group of small farms $100 worth of machinery cares for only 19.7 acres of crop. This amount increases until on the moderately large farm 32.9 acres are handled. This is an important point in view of the fact that it ordinarily costs about one-fifth the value of a machine for each year of use.

In the matter of efficiency in the use of land, the advantage appears to be with the small farm. On the larger farms the land is not utilized as fully as should be the case. This probably is due more to the larger amount of summer fallow on the large farm than to any other cause. In all probability there is also a greater amount of tillable land in pasture on the large farm than on the smaller one. This handicap, however, is nowhere near great enough to offset the great advantage that comes to the large farm by virtue of its ability to make a much better use of labor and equipment. On the largest farms, however, poor utilization of land combined with low crop yields has resulted in a low labor income.

When we stop to consider the matter, there is every reason in the world to expect that a farm business of moderately large size should pay better than a small business. It is an infinitely easier task to make a profit out of a binder that cuts 100 acres of grain a year than it is to make a profit out of one that cuts only a third as much. It is much less a problem to make a profit out of $100 worth of hired labor that takes care of 20 acres of crop than it is to make a profit out of an equal amount of labor that takes care of only two-thirds as much. It is far less difficult to make a profit from the use of a work-horse that takes care of 25 acres of crop than it is to make a profit from one that takes care of only 16 acres. A proper size of business probably contributes as much to a satisfactory labor income in this region as does any other one factor.

SUCCESSFUL SMALL FARMS

The amount of data at hand is not sufficient to permit the drawing of any very definite conclusions as to factors that are

especially important in connection with the profit to be obtained from the small farm. However, there are a few small farms that stand distinctly above others in their group as far as labor incomes are concerned. Careful study of these farms shows that they differ distinctly in organization from other farms in the group that are less profitable. While, as mentioned before, the data are insufficient to warrant the drawing of definite conclusions, we feel that the duty of this report would not be fully accomplished were we not to call attention to these factors at this time.

In the group under study there are thirty-two farms with an average size of 93 acres. The average labor income for these farms is $447. Six farms in this group have an average labor income of $1,617. As mentioned before, comparison of these six farms with others in the same group discloses the fact that there are some important differences in organization as shown in Tables XXX and XXXI.

The thing to be particularly noted from Table XXX is the fact that the successful farms have a much higher percentage of their capital invested as working capital than is the case on the average small farm. This would indicate that the successful farms are more

TABLE XXX. AMOUNT OF CAPITAL, PER CENT OF WORKING CAPITAL, AND LABOR INCOME FOR GROUP OF SMALL FARMS AND SIX MORE SUCCESSFUL OF THIS GROUP

	Capital invested	Per cent working capital	Labor income
Average small farm	$13,304	18.2	$447
Six successful small farms	12,823	28.5	1,617

TABLE XXXI. OTHER FACTORS AFFECTING PROFITS ON GROUP OF SMALL FARMS AND SIX MORE SUCCESSFUL OF THIS GROUP

Factors	Average small farm	Six successful small farms
Crop index	87	105
Acres per animal unit	20.7	7.1
Per cent of receipts from stock	39.7	66.3
Receipts from stock per animal unit	81.60	135.00
Per cent of value of crops sold	73.6	64.0

highly equipped than are others in the group. Data that will be shown subsequently corroborate this evidence.

From Table XXXI it will be noted that one of the most important differences between the two groups of farms is in crop yields. The successful farms have a crop yield 5 per cent above the average of the region while the others have a yield 13 per cent below the average.

Another important difference is in the amount and quality of stock. The successful farms have a productive animal unit for each 7.1 acres while the others have one for 20.7 acres. It will be noted that the quality of animal production is high in each group but astonishingly high on the more successful farms where a receipt of $135 per productive animal unit is obtained. The successful farms also appear to feed a larger percentage of their crop than do others.

Summing the matter up, the more important differences between the average small farm and the more successful small farms may be enumerated in a sentence as follows. The more successful farms are better equipped, have better crop yields, and have much more stock and stock of higher quality than has the average farm in this group.

There appears to be an opportunity even on the small farm of achieving a moderate success where farms are well equipped and a great deal of care is given to the matter of keeping quality of crop and livestock production at a very high level. It might be mentioned, too, that some special training and ability are necessary for managing a farm in this way. The more successful farms in nearly every case have pure-bred livestock, which made the high receipt per productive animal unit possible and made feasible the feeding of a larger percentage of high priced feed than would be practical with ordinary stock. Most of the animals, too, were sold for breeding purposes, which made it necessary for the operators to have some special ability in finding an outlet for their product.

The degree of ability required to achieve a success on the small farm, if employed on a farm of moderately large size, would no doubt result in a labor income at least twice as large as is possible on the small farm. Yet there appears to be a chance on the small farm of doing very well if proper attention is given to the matter of well equipping the place and maintaining a high standard of crop and livestock production.

LAND TENURE

LABOR INCOMES OF FARM OPERATORS WITH DIFFERENT TYPES OF LAND TENURE

Farm operators in the Gallatin Valley may be divided on the basis of land tenure into three classes: first, owners or those that own all of the land that they operate; second, part owners or those that own a part of their land and rent a part; and third, renters or those that rent their entire holding. Of the farms included in this study there were found to be one hundred and twelve owner farms, sixteen part-owner farms, and fifty-eight tenant farms. Because of the lack of a sufficient number of farms to make reliable averages, the part-owner group has been omitted from the following tabulations.

From Table XXXII it will be noted that, contrary to the general opinion on this point, farms operated by tenants appear to be even more efficient in general management than those operated by owners. Tenant farms show an average farm labor income of $605 while those operated by owners have a labor income of only $474. There is even a wider difference than this between the labor income received by the operators themselves, tenants receiving a labor income of $922 while owner-operators receive but $474. Landlords in this region receive an interest rate of 4.6 per cent on their farm investment. The profits of landlords and the relative profits of operators under different forms of tenure are about as we would expect to find them in the light of numerous investigations that have been made in other States.

In well developed agricultural regions the speculative value of land outruns the actual value to such an extent that it is only in rare cases that the average landlord receives the market rate

TABLE XXXII. FARM LABOR INCOME, OPERATOR'S LABOR INCOME, AND LANDLORD'S INTEREST ON INVESTMENT ON FARMS OPERATED BY OWNERS AND TENANTS

Tenure	Farm labor income	Operator's labor income	Landlord's interest on investment
Owners	$474	$474	
Tenants	605	922	4.6 per cent

of interest on his invested capital. For this reason it is more difficult for the farmer who owns his farm to make a good labor income than it is for the renting operator to do so. However, there are other considerations which make it worth while for a farmer to own his farm as soon as he is able to acquire one and properly organize and equip it. Aside from the degree of satisfaction that comes to a person through being master of his own estate, there is the matter of increasing value of lands that should not be overlooked. It is safe to say that the average farmer at present has derived more profit from this source than he has from the actual operation of his farm. In all probability this factor is at present and will continue to be in the future of much less importance than it has been in the past. We shall never again witness the remarkable increase in land values that took place during the years 1900 to 1910. Land will continue to rise in value but much more slowly than has been the case in the past.

TYPE OF TENURE RELATED TO FARM ORGANIZATION

Table XXXIII shows differences in organization between farms operated by owners and those operated by tenants, which account for the differences in farm labor income. It will be seen that owners have the advantage of better quality of both crop and livestock production. They also appear to have an amount of stock that comes nearer being adequate. These factors, however, do not

TABLE XXXIII. DIFFERENCES IN ORGANIZATION BETWEEN FARMS OPERATED BY OWNERS AND THOSE OPERATED BY TENANTS

Factors	Owners	Tenants
Size of farm: Total acres	255	275
Crop acres	182	203
Total capital	27,677	27,205
Operator's capital	27,677	3,239
Per cent of tillable area in crop	78.9	82.3
Per cent of total value of crop sold	71.5	80.6
Acres per productive animal unit	22.2	37.7
Per cent of crop-and-stock receipts from stock	33.4	21.6
Receipts from stock per productive animal unit	72.82	65.60
Crop index	89.8	81.0
Diversity index	3.2	3.0

appear to balance the benefits derived from a better utilization of land on the tenant farms combined with a larger size of business and a greater amount of cash crop.

The farmer who owns his land is in all probability conserving his fertility to better advantage than is the one who rents, as indicated by the higher crop index on the owner farms. The farmers of either group could improve their conditions considerably by changes in their farm organization, the tenants by securing more and better livestock and consequent better crop yields and the owners by increasing their crop area so as to have a larger amount of cash crop to sell.

SYSTEMS OF RENTAL

There are three general methods of land rental employed in this region. The most common method is the share of crop, where the landlord furnishes land and no equipment and ordinarily receives a third of the crop although the exact share varies more or less. Another general method with more or less variation is that where the landlord furnishes the land, half of the feed and seed, and half of the productive livestock, and receives in return one-half of all the receipts of the farm business. A system of rental that is practiced less extensively than any of the others is the cash rental. According to this system the landlord furnishes land only and receives a given amount per acre in cash rent. The average cash rental in this region is $5.93 per acre. The number of farms under each system of rental is as follows: share of crop, 28; share of receipts, 19; cash rental, 9. The number of farms in the latter group is insufficient to give reliable averages and these farms are not included in the following tabulations.

PROFITS OF TENANTS AND LANDLORDS WITH DIFFERENT SYSTEMS OF RENTAL

It will be noted from Table XXXIV that farms rented on the "share-of-receipts" basis are considerably more profitable to both tenant and landlord than are the "share-of-crops" farms. This is particularly noticeable when the farm labor incomes are taken into account. The former have a farm labor income of $714, while the latter have an income of only $469. This would indicate that the farms rented on a share-of-receipts basis are organized much more efficiently

than those rented on a share-of-crop basis. Reference to Table XXXV will show these differences in farm organization in the two groups.

TABLE XXXIV. FARM LABOR INCOME, OPERATOR'S LABOR INCOME, AND LANDLORD'S INTEREST ON INVESTMENT WITH DIFFERENT SYSTEMS OF RENTAL

	Share-of-crop	Share-of-receipts
Farm labor income	$469	$714
Operator's labor income	876	933
Landlord's interest on investment	4.1%	5.1%

SYSTEMS OF RENTAL RELATED TO FARM ORGANIZATION

From Table XXXV it will be noted that the share-of-receipts farms have a distinct advantage in nearly all particulars. They have a much more favorable size as shown by total acreage, crop acreage, and total capital. They are much better equipped with stock as shown by a more favorable percentage of receipts from stock and almost double the number of productive animal units per given unit of farm area. They also appear to be ahead when it comes to the matter of quality of crop production. The share-of-crop farms appear to have a slight advantage in the matter of livestock quality, utilization of land, and amount of cash crop. In

TABLE XXXV. SHARE-OF-CROP AND SHARE-OF-RECEIPT FARMS COMPARED WITH REFERENCE TO DIFFERENCES IN ORGANIZATION

Factors	Share-of-crop	Share-of-receipts
Size of farm: Total acres	277	321
Crop acres	205	231
Total capital	26,995	30,381
Operator's capital	2,911	1,343
Per cent of tillable area in crop	81.5	79.5
Per cent of total value of crop sold	83.1	75.8
Acres per productive animal unit	52.1	23.0
Per cent of crop-and-stock receipts from stock	20.0	26.5
Receipts from stock per productive animal unit	65.40	60.90
Crop index	77.1	80.5
Diversity index	2.9	3.3

the case of the share-of-receipts farms a closer cooperation between landlord and tenant makes it possible for the tenant to run a larger, better equipped and better organized business, thus making a better profit both for himself and for his landlord. In the majority of cases the tenant under the share-of-crop plan is seriously handicapped by not having sufficient capital to provide for a well equipped business of adequate size. It would be to the advantage of all concerned were the share-of-receipt plan used more widely in this region.

FACTORS OF ESPECIAL IMPORTANCE AS AFFECTING FARM PROFITS IN THIS REGION

Careful consideration of the data presented in these pages shows that there are two factors or combinations of factors that dominate the labor income to be obtained from farms in this region to a greater extent than do other factors. They may be stated as follows:

1. A sufficient acreage of crops of good quality.
2. An adequate amount and quality of livestock.

As will be shown later, farms that are organized on this basis have very little chance of meeting with failure.

HOW LARGE SHOULD A FARM BE IN THE GALLATIN VALLEY

It is a little difficult to answer this question definitely. However, I believe the evidence is conclusive that the business should be large enough to give employment to two men throughout the greater part of the year. It should also be large enough to furnish an opportunity for getting maximum service out of all man and horse-labor. In addition to this it should be large enough to permit each item of machinery to be used to its fullest capacity.

In order to fulfill these requirements we feel safe in saying that for ordinary types of farming carried on in this region the farm should contain between 200 and 400 acres. Outside of these limits in either direction we would expect to find a decline in efficiency and a consequent falling off in labor income.

HOW LARGE SHOULD CROP YIELDS BE IN THE GALLATIN VALLEY

With ordinary methods of farming practiced in this region there appears to be little danger of crop yields so large as to affect the

income through the operation of the law of diminishing returns. It is safe to say that crop yields should be at least better than the average of the region. Many farmers are receiving yields at least a fourth better than the average. This would appear to be a goal distinctly worth striving for and would give us yields of the different crops about as follows: wheat, 42 bushels per acre; oats, 71 bushels; barley, 58 bushels; peas, 27 bushels; and hay, 2.9 tons per acre. If care is given to the matter of proper rotation and thorough tillage, it ought not to be difficult to attain these yields in this region.

WHEN IS A FARM WELL STOCKED IN THE GALLATIN VALLEY

Data presented in these pages point definitely to the conclusion that every farm should have enough stock to fully utilize all cheap feeds and waste products but not so much as to require any considerable portion of the feed to be made up of products that have a high market value. Our data indicate that the highest labor income is attained on those farms where about a third or a little less of the crop-and-stock receipts is from stock. I believe that we may safely say, and with extreme conservatism, that with ordinary types of farming not less than one-fourth nor more than one-half of the crop-and-stock receipts should be from stock. Where animals show a very high income per productive animal unit, heavier stocking than is here indicated is feasible, but this will not hold for ordinary stock such as is kept on the majority of farms in this region.

COMBINATIONS OF FACTORS THAT SEEM TO INSURE SUCCESS IN THIS REGION

To show the effect of these more important factors when combined and to verify the conclusions which we have drawn from this work, farms have been brought together, each of which answers our requirements as far as these main factors are concerned.

Relation of Favorable Size and Crop Yields to Labor Income

Table XXXVI shows a group of twenty-one farms each of which had a total acreage of between 200 and 400 acres and had crop yields above the average of the region. The farms shown in this table include all of those in the region that are properly organized as far as size of business and quality of crop production are concerned. The average size is 300 acres. Crop yields are a fifth better than

the average of the region. The average labor income is $1,884. Four-fifths of the farmers in this group made over $1000, almost a third of them made over $2000.

TABLE XXXVI. RELATION OF FAVORABLE SIZE AND QUALITY OF CROP PRODUCTION TO LABOR INCOMES

Number of farms	Average size	Crop index	Per cent of crop-and-stock receipts from stock	Labor income
21	300 A.	120	20	$1,884

Relation of Favorable Size, Crop Yields, and Percentage of Crop-and-Stock Receipts from Stock to Labor Income

In the group of farms used in Table XXXVI there were found to be seven that in addition to being between 200 and 400 acres in size and having crop yields above the average, received not less than one-fourth nor more than one-half of their crop-and-stock receipts from stock. In Table XXXVII these farms are brought together for the purpose of showing the effect of this added factor on labor incomes. The factors and labor income are given for each farm in this group. The farms shown in this table represent all the farms in this survey that are properly organized as far as the main factors are concerned.

Note the average labor income—$2,510. Examine the labor incomes on the individual farms. Does it look as though farming were much of a game of chance when farms are properly organized?

TABLE XXXVII. RELATION OF SIZE, CROP YIELDS, AND CROP AND STOCK RATIO TO LABOR INCOME

Farm	Total-acres	Crop index	Per cent of crop-and-stock receipts from stock	Labor income
No. 96	240	150	31	$1,829
No. 127	236	116	31	3,888
No. 12	320	104	31	1,225
No. 17	320	133	36	2,216
No. 46	310	115	33	2,770
No. 84	300	129	26	4.413
No. 134	380	112	31	1,395
Average	300	123	31	$2,534

A GALLATIN VALLEY "MODEL" FARM

Farm No. 84 in Table XXXVII has a labor income of $4,413. So far as we know it is the best-paying farm in the Gallatin Valley.

FARM NO. 84

Total area	300 acres
Tillable area	285 "
Waste (creeks, ditches, etc.)	15 "
In crop	210 "
In pasture	75 "

INVESTMENT

	Apr. 1, 1913	Apr. 1, 1914
Real estate	$30,000	$31,000
Machinery and tools	1,115	1,115
Livestock	4,329	6,118
Feed and supplies	828	956
Cash to run farm	500	500
Total	$36,772	$39,689

STOCK PRODUCTS SOLD

Products	Value
Cream	$100
Eggs	100
Wool	73
Total	$273

LIVESTOCK

Kind	Inventory Apr. 1, 1913 No.	Inventory Apr. 1, 1913 Value	Inventory Apr. 1, 1914 No.	Inventory Apr. 1, 1914 Value	Sales No.	Sales Price	Purchases No.	Purchases Price	Died
Cows	9	$675	9	$675					
Yearlings			3	150					
Bulls			1	100			1	$100	
Horses	8	1,600	8	1,600					
Yearlings			2	250					
Colts	2	150	2	150					
Ewes	75	750	120	1,200					
Lambs	68	1,020	102	1,530	27	$405			50
Sows	2	60	7	210			5	125	2
Other hogs			1	50	6	100			
Pigs	8	24	51	153					
Chickens	100	50	100	50					
Totals		$4,329		$6,118		$505		$225	

FARM NO. 84—(Continued)

CROPS

Kind	Acres	Yields		Sales		
		Per acre	Total	Amount	Price	Value
Winter wheat	15	27 bu.	405 bu.			
Barley	65	60 bu.	3,900 bu.	3,900 bu.	$0.56	$2,184
Timothy	80	2 T.	160 T.	100 T.	6.50	650
Peas	50	45 bu.	2,250 bu.	2,250 bu.	1.50	3,375
Total............	210			Total..........		$6,209

FARM EXPENSES

Hired labor	$660
Board, hired labor........................	247
Improvements	1,275
Feed (15,000 lbs. oats)................	127
Seed	81
Horseshoeing	5
Veterinary	7
Breeding fees	40
Binding twine	30
Threshing	325
Taxes and insurance................	175
Total....................................	$2,972

FINANCIAL SUMMARY

	Items	Totals
Capital (average)		$38,230
Receipts:		
Crops	$6,209	
Stock	505	
Stock products	273	
Miscellaneous	......	
Increase inventory ..	2,917	9,904
Expenses:		
General	2,972	
Stock	225	
Decrease inventory		3,197
Farm income		6,707
Interest on capital @ 6%		2,294
Labor income		$4,413

EFFICIENCY FACTORS

Size: Total acres	300.
Man equivalent	2.08
Crop index	129.
Per cent crop-and-stock receipts from stock..................	26.
Acres per productive animal unit..................................	8.60
Receipts from stock per productive animal unit..............	67.36
Per cent of total value of crop sold..............................	91.
Diversity index	3.8
Per cent of total capital in working capital....................	20.7

A detailed record of a year's business on this farm is given above. Careful analysis of the organization of this farm shows that there is little left to be desired. There is hardly any respect in which it could be improved.

This farm offers as good an example of a well organized and well managed farm business as could easily be found. It is large enough to permit the best possible use to be made of all labor and equipment. It has excellent quality of production as shown by a high yield per acre of crops and a high receipt from stock per productive animal unit. It has enough stock to utilize all cheap feeds on the farm and by-products that would otherwise be wasted, but not so much as to prevent the selling of a large percentage of the merchantable crop as a cash crop. All things considered, it would be a difficult matter to find a better organized farm and a better paying one.

SUMMARY

A farm management survey was conducted in the Gallatin Valley, Montana, during the summer of 1914. Records were secured on one hundred and eighty-six farms, representing the business of these farms for the fiscal year beginning April 1, 1913, and ending April 1, 1914.

The average farm labor income on the farms studied was $555. This compares favorably with labor incomes received by farmers in other States.

The amount and the distribution of capital are factors that were found to have a bearing upon labor incomes. As the amount of capital increased, labor incomes correspondingly increased.

Farms that had a large percentage of their capital tied up in real estate did not do as well as those that reserved an amount sufficient to adequately equip and operate their farms.

Farms whose land was valued at $100 per acre made better labor incomes than those with either a higher or a lower valuation.

The degree of diversity appears to have a bearing on labor incomes. As the number of important sources of income increases, the labor income correspondingly increases. A farm with only one or two important enterprises is at a serious disadvantage in the matter of utilizing labor throughout the year and in utilizing by-products of the farm that would otherwise be wasted.

Farms that sell a large percentage of their marketable crops have a better labor income than those that reserve a considerable portion for feed and seed. A good amount of cash crop seems to be of considerable importance as far as labor incomes are concerned.

Peas were found to be the best-paying cash crop during the survey year. Other crops in the order of their profitableness were oats, wheat, barley, and hay.

A very important factor affecting labor incomes in this region is crop yields. A small increase in yield brings a substantial increase in labor income. Farmers should strive to secure crop yields at least better than the average of the region.

Two methods of weed control are practiced in this region—rotation with a sod crop and the summer fallow. If care is exercised in planting clean seed, it is thought that rotation will take care of the weed situation. The summer fallow is impractical on high priced land. Some method must be used that will permit a crop to be grown each year.

Farms are lightly stocked in this region. The average farm in all probability lacks sufficient stock to utilize cheap feeds and waste products.

As the amount of stock on farms increases, the average labor income correspondingly increases. It must be borne in mind, however, that the most heavily stocked farms in this region have only a moderate amount of stock.

Farms receiving a little less than one-third of their receipts from stock have a much better labor income than those that receive either more or less from that source.

The most favorable crop and stock relation seems to be attained on farms that have stock enough to utilize all cheap feeds and waste products but not so much as to require any considerable proportion of their feed to consist of products that have a high market value. Such a policy, if put into effect, would probably increase the amount of stock in this valley.

Farms with a net receipt from stock of at least $50 per productive animal unit have a much better labor income than farms with a smaller receipt from this source.

Factors that have an important bearing on quality of animal production are the rate of loss from death and the percentage of females that bear young each year. Losses from death were found

to be moderate in the case of mature stock but rather heavy in young animals of all classes. A considerable proportion of this loss could be averted by a little more care in feeding and management.

Size of business is a very important factor having a bearing on labor incomes to be attained in this region. The farm that is large enough to employ at least two men throughout the year and to use labor and equipment to fullest capacity has a distinct advantage over the smaller farm. Very large farms, however, because of low crop yields and poor utilization of land, have the lowest labor incomes of all. Between 200 and 400 acres appears to be the most satisfactory size for farms in this region.

There is a chance even on the small farm of achieving a moderate success if attention is given to maintaining the quality of both crop and animal production at a high level. With a high quality of animal production, heavier stocking is feasible than is the case with stock of ordinary quality. The same degree of ability that is necessary to achieve a moderate success on a small farm, if employed on a moderately large farm, will insure a labor income much greater than is possible on the smaller unit.

Tenants in this region receive a somewhat better labor income than do farm owners. The tenant farmers are running a larger business and are utilizing their land to better advantage than are those farmers that own their land. Tenants could improve their condition by securing more and better livestock and owners could improve theirs by increasing their size of business and using their land to fuller capacity.

The two common forms of land rental in this region are the share-of-crop and share-of-receipt. The latter method is found to be by far the more satisfactory to all parties. It results in a better income for both landlord and tenant. Closer cooperation between landlord and tenant under this system makes possible the organization of the farm in a more efficient manner.

Two factors or combinations of factors that are probably of greatest importance as affecting labor incomes in this region are (1) a sufficient acreage of crops of good quality and (2) an adequate amount and quality of livestock. Our data show that farms that are properly organized so far as these main factors are concerned stand little chance of failure.

Farm No. 84, described in this report, leaves little to be desired in the way of efficiency in organization. This farm has a labor income of $4,413.

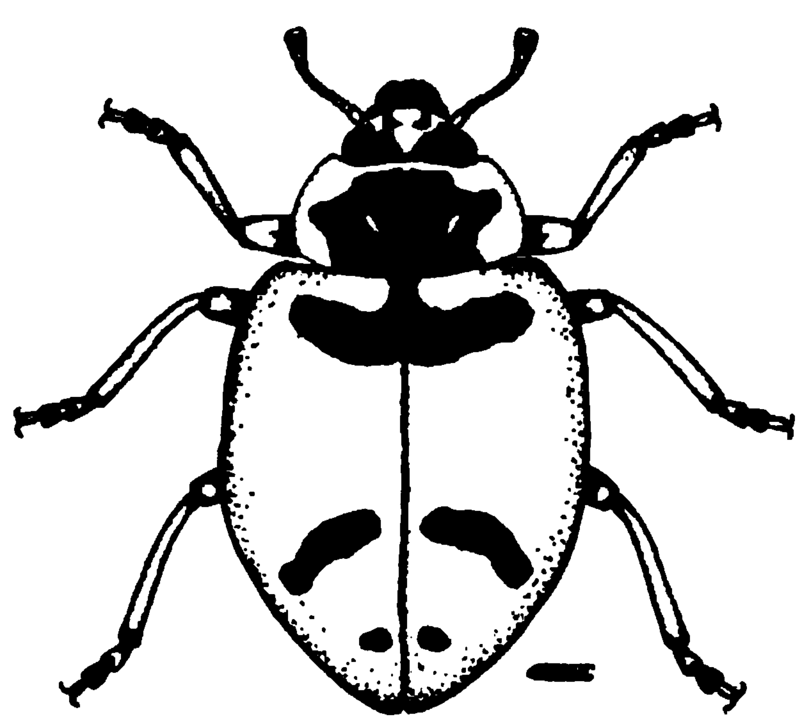
UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

BULLETIN NO. 112 DECEMBER, 1916

Fourteenth Annual Report of the State Entomologist of Montana



The Five-Spotted Ladybug, *Hippodamia 5-signata* Kirby

BY
R. A. COOLEY

Fourteenth Annual Report of the State Entomologist of Montana

INSECT PESTS OF 1916

THE MITES AND TICKS (ACARINA)

The Pear-Leaf Blister-Mite (*Phytoptes pyri* Pagnat). The pear-leaf blister-mite was reported as doing a great deal of damage to apple trees in the Bitter Root Valley during the past season. Further experimental work in the control of this insect has been outlined for next season.

THE BRISTLE TAILS AND SPRING TAIL (THYSANURA)

The Fish Moth (*Lepisma saccharina* Linn.). As usual there were several inquiries regarding the fish moth, which seemed plentiful in warm closets and cellars.

The Snow Flea. Several reports were received, accompanied by cans containing millions of specimens of a black Collembolan, which is more or less plentiful on standing water. This year it was unusually abundant, even on damp rotted boards, leaf mold and old rags. No damage could be attributed to it.

Collembola in the Soil. Reports were received regarding a tiny, white Collembolan, which was found to be plentiful in the soil in greenhouses but not doing any apparent damage. In the college greenhouses we have found what is apparently this same insect injuring leaves of cucumber that were near the ground.

COCKROACHES AND GRASSHOPPERS (ORTHOPTERA)

The German Cockroach (*Blatta germanica* Linn.). Inquiries regarding the control of cockroaches were frequent. The most common one was the German cockroach, *Blatta germanica.* The Oriental cockroach, *Periplaneta orientalis,* was also reported but not as being abundant.

Grasshoppers (*Acrididae*). There was no serious outbreak of grasshoppers this year, but late in the summer small outbreaks were reported from widely separated communities. The species which appeared to be doing the most damage was *Melanoplus atlanis.* Owing to its appearing late in the season, this insect did its greatest

damage by climbing the full-grown grain stalks and cutting off the heads. Slight injury was done also to newly seeded winter wheat. In the early spring, about the first of May, grasshoppers were surprisingly abundant north of Miles City. No specimens were sent us and we cannot state what the species was.

The Sand Cricket (*Stenopelmatus* sp.). More inquiries than usual were received regarding the sand cricket or Jerusalem cricket. Several specimens were sent in as curiosities, with requests for information.

THRIPS (THYSANOPTERA)

A Grain Thrips (*Anaphothrips striatus* Osb.). There was a considerable loss in oats, with a slighter loss in barley and wheat, due to a sterility of the florets caused by the feeding of this thrips. In several instances, especially where the head had not completely emerged from the boot, live specimens of thrips were secured, which were determined as this species. In several sections oat fields were examined and the loss from this insect was estimated at about 10 per cent.

The Onion Thrips (*Thrips tabaci* Lind.). The onions growing on the experiment plots on the college farm were found to present a rather sickly appearance, which was at first attributed to hail injury. Closer examination revealed the fact that the injury was mostly due to the onion thrips. Adults and young were both found in great numbers on the leaves.

Thrips on Nasturtiums. Nasturtium leaves were sent in for examination which showed typical thrips injury. A few of the thrips were found but they were dead and so dried and broken that it was impossible to make a determination of the species.

THE TRUE BUGS, PLANT LICE, ETC. (HEMIPTERA)

The Bedbug (*Cimex lectularius* Linn.). Requests for information about bedbug control were fully as numerous if not more so than in previous years. It is hoped to publish a leaflet containing an account of the habits and control methods of the bedbug for distribution before next season.

The Chinch Bug (*Blissus leucopterus* Say). This insect was reported from three different localities, but as no specimens were sent in for identification the reports have not been verified. The chinch bug occurs, so far as we know, only in a few counties in

northern Montana, where no damage to speak of has been done. It is not likely that this insect will be very injurious in our climate.

The False Chinch Bug (*Nysus angustatus* Uhl.). This insect is rapidly becoming a pest in the State, and this year it has been reported as being exceedingly plentiful in grain fields. It is often mistaken for the real chinch bug and is the cause of many of the chinch bug reports received at this office. In one instance this insect was found in great numbers, in all stages of development, on an old discarded mattress.

The Buffalo Treehopper (*Ceresa bubalus* Fab.). Very often a man walking through an apple orchard will notice twigs, and at times most of a tree, which show a peculiar, gnarled or stunted appearance. These twigs on closer examination will be seen to have scars or tiny incisions, which give them a decidedly "braided" appearance. These are the results of the egg punctures of the buffalo treehopper, and while the insect does not feed on the apple, these egg punctures may be the cause of more or less stunting or killing of twigs or whole trees. Inquiries concerning the cause of this injury are frequent.

The White Fly (*Aleurodes vaporariorum* West). The greenhouse white fly was the cause of considerable annoyance and loss to greenhouse men all over the State. Requests for control information were frequent. We have known of the presence of this insect for many years.

The Green Apple Aphis (*Aphis pomi* DeG.). The green apple aphis was not as abundant as formerly, but was reported from various parts of the State as doing slight damage to apple trees. Our experience has been that this insect continues in destructive abundance year after year.

The Western Wheat Aphis (*Brachycolus tritici* Gill.). This wheat aphis was scarce this year, being found in only one or two scattered localities. The severe winter which killed off much of the winter wheat, may have killed off a high percentage of the lice.

The Woolly Apple Aphis (*Schizoneura lanigera* Hausm.). This injurious insect is becoming one of the most serious pests to apples in the Bitter Root Valley. Owing to lack of funds it has been impossible to do any work on its control.

MOTHS AND BUTTERFLIES (LEPIDOPTERA)

The Imported Cabbage Worm (*Pieris rapae* Linn.). This cabbage worm was as plentiful as in previous years and attracted considerable attention. Cabbage patches all over the State suffered some loss from it. Wherever the remedies we have proposed have been used, the insect has been controlled.

Clothes Moths (*Tinea* sp.). Clothes moths were reported in several instances as being harmful. Fumigation with hydrocyanic acid gas was tried and was successful in controlling them.

The Bud-Moth of Apple (*Tmetocera ocellana* Schiff.). This insect appeared in an unusual role on apples this year. The tiny larvae fed on the fruit just before picking time, making holes and scars on the surface. While the damage to each fruit did not amount to much, it was enough to drop first-class fruit into the cull class and cut down the value of the crop.

The Mediterranean Meal Moth (*Ephestis kuehniella* Zell.). The Mediterranean meal moth was reported in corn meal in town, and again in the feed bins of the poultry department at the Experiment Station. The ground feed in the bins became so matted together that it was difficult to get it out. This is an important pest in flour-mills, warehouses and stores.

The Polyphemus Moth (*Telea polyphemus* Cramer). The cocoons of the polyphemus moth were collected at Huntley. There is no record of any damage being done, but persons who find any of the very large and showy moths often send them in.

The Red-Humped Apple Caterpillar (*Schizura concinna* S & A). This insect pest of the apple was reported from the Bitter Root Valley but was doing no great amount of damage. It occasionally eats off the foliage from a few small limbs.

The Sugar-Beet Webworm (*Loxostege sticticalis* Linn.). In late July and early August reports of damage being done by the sugar-beet webworm were frequent. They were at first reported as feeding on Russian thistle, but later fed on flax and sugar beets. It seems clear that this injury was by the second brood of the insect.

The Tent Caterpillar (*Clissiocampa americana* Fab.). Several large nests of the tent caterpillar were noticed on apple trees in various localities. They did not seem to be doing any extensive damage but, as usual, were defoliating a few branches.

FLIES (DIPTERA)

The Currant Fruit Fly (*Epochra canadensis* Loew.). The currant fruit fly continues to do as much damage to currants as in previous years. As yet no entirely satisfactory control measure has been found for this pest.

Horse Flies (*Tabanidae*). Horse flies were as abundant as usual, and pestered the picnickers and campers as well as horses in the canyons about the State.

The March Fly (*Bibio albipennis* Say). Larvae of a Bibio, probably *albipennis*, were sent in with requests for information. So far as is known, these insects caused no damage whatever, but their presence in garden soil in great numbers aroused suspicion.

The Nose Fly (*Gastrophilus haemorrhoidalis* Linn.). The nose fly, while plentiful, is not recorded as having made any great advance in its spread this season. Some interesting facts regarding the egg and egg-laying habits of this fly were brought out this summer by Dr. R. R. Parker, of the Board of Entomology. These have recently appeared in the Journal of the New York Entomological Society.

The Onion Maggot (*Phorbia ceparum* Meade). The onion maggot was abundant this year and completely destroyed several rows of onions on the plots at the Experiment Station. Reports of damage done by this insect were received from various parts of the State.

Wheat Stem Maggots (*Meromyza americana* Fitch and *M. nigriventris* Macq.). There was no report of serious injury by the wheat stem maggot until the latter part of July. The damage at this time was done to the plant while in blossom. The stalk was cut just above the last node, causing the head to die, while the leaves appeared perfectly healthy. This trouble was general in Montana.

BEETLES (COLEOPTERA)

Blister Beetles (*Epicauta maculata* Say and *E. pennsylvanica* D. G.). These two species of blister beetles were reported as being injurious to sugar beets. They are both common in Montana and have been injurious for many years.

Nuttal's Blister Beetle (*Cantharis nuttalli* Say). This blister beetle was reported from the Judith Basin Substation as feeding on

horse beans on the forage crop plots. It is a common native species which feeds on a great variety of plants.

The Bumble Flower Beetle (*Euphoria inda* Linn.). The bumble flower beetle was reported again this year, eating the kernels from the almost ripened ears of corn. It does not seem to be abundant enough to cause any great amount of damage.

The Colorado Potato Beetle (*Leptinotarsa decimlineata* Say). The Colorado potato beetle was abundant, and at the Huntley Experimental Farm it completely cleared off the dry-land potato plots in spite of three applications of arsenicals. In this instance the insects were present in very unusual numbers.

A Cottonwood Beetle (*Monoxia debilis* Lec.). For the first time, this beetle has been reported as doing considerable injury to cottonwoods. Specimens were sent in from several localities and were determined as this species.

The Cottonwood Leaf Beetle (*Lina scripta* Fab.). Many reports were received regarding the cottonwood leaf beetle, which seemed to be unusually common this year. It was especially harmful to nursery stock. In one instance it was so plentiful that arsenicals did not prevent damage to the trees.

Cottonwood Mining Beetle (*Odontota* sp.). This cottonwood miner was not as plentiful as usual, though reports of it were received from widely separated localities. Some years it almost completely blackens the foliage of the cottonwood tree.

The Larder Beetle (*Dermestes lardarius* Linn.). This common American and European household pest was sent in a number of times as in previous years and was especially harmful to stored food products in private houses.

The Rosebud Curculio (*Rhynchites bicolor* Fab.). The rose curculio did some damage to cultivated roses but was not as abundant as previously.

The Spinach Carrion Beetle (*Silpha bituberosa* Lec.). There was considerable damage to sugar beets in some localities due to this insect. This damage was not as extensive as in some previous years.

The Ten-lined Leaf Chafer (*Polyphylla decimlineata* Say). There was one request for information about this large and showy beetle. It was doing no damage but merely had aroused the curiosity of the finder.

Wireworms (*Elateridae*). Wireworms were not as troublesome as in previous years and no large areas of wheat were reported injured by them. There was a report of wireworms doing damage to potato tubers, but this was not extensive.

BEES AND ALLIED FORMS (HYMENOPTERA)

Alfalfa Seed Chalcid (*Bruchophagus funebris* How.). The alfalfa seed chalcid was found in the seeds of volunteer red clover in the western part of the State. An examination of clover seed sent into the State Grain Laboratory from various localities for testing, has not resulted in finding any more evidence of this very injurious insect.

The Leaf Cutter Bees (*Megachile* sp.). These bees drew considerable attention this season when the cut leaves of shade trees and shrubs were noticed. This insect cuts leaves of corn, roses, poplar, lilac, box elder and many shade trees. The nests were found in the soil and sent in by one inquirer.

THE OFFICE OF STATE ENTOMOLOGIST IN MONTANA

Many of the States in this country maintain a separate office of State Entomologist at a considerable expense in order that in addition to the research conducted at the Agricultural Experiment Station the various phases of the practical control of pests may be adequately cared for.

By an act of our legislative assembly approved March 4, 1903, the entomologist of the Experiment Station was designated as State Entomologist. He receives no compensation for his services other than that received from the State College but his necessary traveling, office, and laboratory expenses are paid from a small fund appropriated for the purpose. This sum was $300 for the first year and was gradually increased during the following twelve years until $2000 was appropriated. The last legislature appropriated for the expenses of the State Entomologist the sum of $2700, but on account of shortage of funds only $2000 was allowed by the State Board of Examiners.

This office has now been established fourten years and during this time has witnessed many outbreaks of pests, some of which have been severe. It is believed that very much has been done to alleviate these outbreaks and that large sums of money have been saved to our farmers, gardeners, stockmen, and fruit growers.

Several additional laws have been passed, placing new duties on the State Entomologist. Including the original act, they are as follows:

State Entomologist Law: Session Laws, Eighth Legislative Assembly 1903, Chapter 59 (p. 124).

Insecticide and Fungicide Law: Session Laws, Twelfth Legislative Assembly, 1911, Chapter 26 (p. 38).

Pests and Plant Diseases Quarantine Law: Session Laws, Thirteenth Legislative Assembly, 1913, Chapter 61 (p. 117).

State Board of Entomology Law: Session Laws, Thirteenth Legislative Assembly, 1913, Chapter 120 (p. 466).

The duties of the State Entomologist are in addition to his regular duties at the State College and Experiment Station.

The duties of the State Entomologist's office alone have grown year by year until they require a large amount of time and labor. In June, 1916, an assistant on part time was employed to be the representative of this office in carrying out the provisions of the State Entomologist law. The man appointed is Mr. Howard L. Seamans, a graduate in entomology from this college in the class of 1916. He is well qualified both by training and natural abilities for his position. Two-thirds of his time is given to the work of this office and for this service he receives $800 per annum, the remainder of his salary being paid by the college for teaching.

REVIEW OF THE PRINCIPAL STATE INTERESTS IN ENTOMOLOGY IN 1916

THE ALFALFA WEEVIL

The alfalfa weevil is not a destroyer of alfalfa seeds as is often thought, but feeds both as a larva or grub and as an adult beetle on the green foliage of the alfalfa plant. This insect has been in Utah in injurious abundance for a considerable number of years and in recent years it has spread to the States of Idaho and Wyoming. Much damage has been done to the alfalfa industry in localities where the insect has been long established. Special and vigorous measures for the control of the alfalfa weevil are necessary where it is abundant, in order to secure a profitable crop of hay. To put these measures into operation and follow them energetically as must be done, is expensive. It is highly desirable, therefore, that

this insect be prevented, if possible, from gaining entrance into Montana. To this end, as has been previously reported, a quarantine has been established by proclamation of the Governor, which permits certain classes of agricultural products to be admitted into Montana only under rigid regulations. It is believed that this quarantine will do much to prevent or delay the introduction of this insect, which, if it should gain admittance and become established, would probably destroy annually many thousands of dollars worth of property for Montana farmers.

The first quarantine in Montana was established in 1913, and since that time further information regarding the alfalfa weevil has been accumulated by those who have been giving special attention to the subject. During the spring of 1915 a conference of the official entomologists of the western States was held at Salt Lake City, together with representatives of the State of Utah, the United States Bureau of Entomology and the Utah Experiment Station, for the purpose of acquiring all the information possible, exchanging ideas, and, if possible, agreeing on uniform regulations to be recommended to the several States for their consideration. The conference was very profitable for all and uniform recommendations were adopted. These recommendations became the basis of a revised quarantine proclamation, which was issued by Governor S. V. Stewart on June 24, 1916.

This proclamation follows:

Quarantine Proclamation

Whereas, It has become known to me that an injurious insect, popularly called the alfalfa weevil, and scientifically known as *Phytonomus posticus*, exists and is dangerously injurious to alfalfa in the State of Utah, and in certain counties in the State of Idaho, to-wit: Bear Lake, Oneida, Bannock, Franklin and Power, and in certain counties in the State of Wyoming, to-wit: Unida and Lincoln.

Now, therefore, I, S. V. Stewart, Governor of the State of Montana, under and by virtue of the authority conferred upon me by Chapter 61 of the Session Laws of the Thirteenth Legislative Assembly, do hereby declare and proclaim a quarantine against said State of Utah, and said counties of Bear Lake, Oneida, Bannock, Franklin and Power, in the State of Idaho, and the counties of Unida and Lincoln in the State of Wyoming, and forbid the importation into Montana of the following agricultural products and other articles, excepting under conditions and regulations as specified:

1. Alfalfa hay and other hays of all kinds, and cereal straws.

2. Fresh fruits and vegetables, exclusive of potatoes, excepting under the following regulations;

a. Shipments for Montana to be made only from points designated by the recognized State pest inspection officer of the State shipping into Montana, said officer to notify the State Horticulturist of the State of Montana by registered mail, or by telegraph, of the designation of all shipping points in the aforesaid State of Utah or counties of Bear Lake, Oneida, Bannock, Franklin and Power in Idaho, or counties of Unida and Lincoln in Wyoming; said notification to be sent, and its receipt to be acknowledged, before any shipments are made to the State of Montana from said designated points.

b. Shipments to be repacked from orchard or field boxes into new, clean boxes, or other fresh containers.

c. All wagons or other conveyances used in hauling to the place where repacking is conducted to be kept free of alfalfa hay, other hays, straw, and all other means of contamination.

d. All packing houses to be at all times free of alfalfa hay, other hays, straw, and other means of contamination.

e. Each package to be plainly stamped or tagged with an official certificate of the State from which the shipment originates, stating that it has been inspected and passed in compliance with these regulations and stating where it was repacked and inspected.

3. Potatoes unless accompanied by an official certificate signed by the recognized State pest inspection officer of the State from which such shipments of potatoes originate, setting forth that the potatoes have been passed over a screen, placed in fresh, clean sacks and packed in cars that are free of alfalfa hay or other means of contamination.

4. All nursery stock, unless accompanied by a special certificate setting forth that such nursery stock has been fumigated for the alfalfa weevil in an air-tight enclosure subsequent to being boxed, baled or packed for shipment, with cyanide of potassium or cyanide of sodium at the rate of one ounce to each one hundred cubic feet of enclosed space.

5. All agricultural emigrant movables, unless accompanied by an official certificate of inspection made under oath and setting forth that such agricultural emigrant movables have been inspected and found to be free of contamination by alfalfa hay, all other hays, and cereal straw.

6. All railway shipments of livestock unless shipped in cars that are free of alfalfa hay, all other hays, and cereal straw, throughout all that portion of the journey that is within the State of Utah and counties of Bear Lake, Oneida, Bannock, Franklin and Power in Idaho, and counties of Unida and Lincoln in Wyoming.

All Horticultural Inspectors of the State of Montana are hereby instructed and required to refuse admission into the State of Montana to all such articles as are herein designated from said State of Utah and counties of Bear Lake, Oneida, Bannock, Franklin and Power in Idaho, and counties of Unida and Lincoln in Wyoming, except under the conditions herein enumerated. If any such articles as are hereinbefore listed be shipped into the State of Montana in violation of this quarantine they must be at once destroyed or returned to the shipper at his expense.

This quarantine shall not be construed to interfere with shipments of produce to the Yellowstone Park over the Oregon Short Line Railroad, and to Idaho points via Montana over the Gilmore and Pittsburg Railroad.

This quarantine shall take effect and be in force on and after the first day of July, A. D. 1916.

It is specifically understood and intended that this quarantine proclamation shall revoke all previous proclamations on this subject by me made.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State to be affixed.

Done at Helena, the Capital, this the twenty-fourth day of June, in the year of our Lord one thousand nine hundred sixteen.

S. V. STEWART

By the Governor:
A. M. ALDERSON
Secretary of State.

THE ARMY CUTWORM

The army cutworm is one of our most important pests in Montana. In a previous publication we have stated that in the year 1915 about 100,000 acres of spring wheat was eaten off, requiring reseeding, and that this insect in that one year cost the State on wheat alone at least $925,000. This loss would have been very much greater had it not been for the use of remedies which were brought to the attention of grain growers through the press and by correspondence. From all over the State we were assured that the remedy proposed, namely, the use of poisoned bran mash, was very effective. Much more grain could have been saved if this office had been notified earlier. This insect feeds on a wide variety of crops and plants and is capable of doing immense damage to agriculture in Montana in the years to come.

This outbreak afforded an opportunity which we had long been seeking to study the early stages and habits of the insect. Excellent

progress was made and a paper giving the results of the studies has been published in the Journal of Agricultural Research.

As a result of our studies it now seems clear that this insect is present in greater or less numbers every year and that there is probably some unsuspected damage done each season. During the spring of 1916 very little damage was reported. This further verifies our previous experience, which is that the army cutworm does not generally appear in very destructive numbers two years in succession.

From reports and specimens which have been sent to us this fall (1916) it is feared that some parts of the State will again be visited by these cutworms in the spring of 1917. From two localities in central Montana we have information that the very small cutworms were very abundant in October and that fall-planted wheat was completely eaten up. If further study of the situation indicates it to be desirable, warnings will be sent out in the spring.

THE WHEAT SHEATH MINER

(*Ceredonta femoralis* Meigen)

It is impossible to say at the present time how important the wheat sheath miner will become in Montana. There is almost no literature concerning it.

This insect is widely distributed in the State, but we have definite information regarding serious damage in only one locality in Missoula County. In one field of wheat it was found by actual count that 95 per cent of the plants were more or less injured, while an adjoining field of oats had 12 per cent damage. What we now know about this insect seems to indicate that it is a species which continues in destructive numbers year after year.

During the past two years an assistant, Mr. H. L. Seamans, has worked out the life history and habits of this important insect quite completely and a paper on the subject has recently been submitted for publication.

SUGAR-BEET ROOT-LOUSE

(*Pemphigus betae* Doane)

Extensive experiments in the control of the sugar-beet root-louse by irrigation were carried on at Huntley, under the Adams Fund. This is the third year that the work has been pursued and the results continue to be very satisfactory. It has been found that

not only is the root-louse controlled but that the tonnage and sugar content of the beets are distinctly increased by the method of irrigation advocated. It seems clear that this work will lead to very largely increased financial returns to sugar beet growers in Montana and other western States.

THE LESSER CLOVER LEAF WEEVIL

(*Phytonomus nigrirostris*)

During the past two years the lesser clover leaf weevil has appeared in great numbers and has been doing damage in one valley in western Montana. The insects feed on the growing clover and are found principally in the terminal growth and opening blossom heads. The larva or grub looks very much like the alfalfa weevil and might easily be mistaken for that insect.

This office has given careful attention to this weevil during the last two years and will continue the study when there is an opportunity.

THE SPINOSE EAR TICK

(*Orinthodoros megnini* Duges)

One of the surprises of the past year was the discovery of the Spineose ear tick on cattle in eastern Montana. This tick has the habit of infesting the ear passages of its host. Surprisingly large numbers of these ticks were taken from the ears of calves and young stock. The effects noted here are much the same as in other parts of the country. Infested stock is irritated and does not do well. Some lose flesh and some die. From what we know at the present time, it seems clear that this tick is present in several counties.

This has been looked upon as a southern species. It occurs in Mexico and in some of the southern States, but it was not supposed that it could endure our climate and be abundant enough to be injurious. In looking up its occurrence in Montana, it was learned that it had been present in the same localities for several years and we now think that this tick is liable to be an important pest. Further attention will be given to it and though no satisfactory remedies are now known, it is hoped that some may be found.

FOUL BROOD OF BEES

In each annual report of the State Entomologist since 1911, urgent attention has been called to the presence and rapid spread of American foulbrood disease in bees in Montana. We knew of it

soon after this disease came into the State but at that time the infection was confined to a small locality. At the present time it is known to be present not only in the Yellowstone Valley, where it first appeared, but as far west as the Bitter Root Valley. Both in the Gallatin Valley and in the Bitter Root Valley it is known to be rather common. No canvass or survey of the State has been made, but it is almost certain that this highly destructive disease of bees is now general in its distribution wherever bees are kept in Montana. We know of numerous beekeepers who are fighting a losing battle because they do not know how to combat the disease. Many have been driven from the industry already and it is as certain as can be that others will follow unless adequate statewide means of control are adopted.

Beekeeping is a natural and profitable part of diversified agriculture. Properly protected, the industry will annually yield a large profit to rural Montana. Experience has shown that the general run of beekeepers cannot control this disease unaided. The usual method is to have a law on the statutes providing for an inspector, who has authority to examine all bees and instruct how to eradicate the disease. He has authority to destroy bees that are not treated in accordance with his instructions, but he does not have to use this authority often. Beekeepers who wish to continue in the industry generally are glad of the assistance given by the State expert. The inspector, being a well informed man, naturally gives much valuable instruction in beekeeping. He becomes to a considerable extent a traveling instructor and his influence toward building up the bee industry is distinctly felt. Such a law further provides for defense against the introduction into the State of diseased bees or contaminated materials from other States.

The duties of an inspector of apiaries probably connect up with the State Entomologist's office more closely than with any other department of the State's service. The duties could be assigned to the State Entomologist provided sufficient funds were appropriated to employ a deputy for this particular duty. The inspection work alone would not be sufficient to employ the full time of a man. A part of his time might be employed in inspection and the remainder paid for by the Agricultural College for instruction of students in beekeeping or by the Experiment Station for research work, or a man might be temporarily employed during each summer.

By the latter way, however, it might be difficult to get the services of a competent man.

Experience has shown in other States that the inspection service greatly reduces the amount of disease, reestablishes confidence and permits the industry to build up again. Such a law should be passed in Montana.

NOTES ON THE MORE COMMON MOSQUITOES OF MONTANA

By J. R. Parker

That mosquitoes have long been troublesome in Montana is shown by referring to the Lewis and Clark Journal. Thus we find the following entries made by Lewis while the expedition was in the Missouri river valley between Canyon Ferry and Lombard: July 13, 1805, "It is impossible to sleep a moment without being defended against these (mosquitoes) most tormenting of all insects." July 19, 1805, "Musquetoes very troublesome to us as usual." On the return trip, while on the lower Yellowstone Captain Clark made the following entries: August 3, 1806, "Last night musquetoes were so troublesom that no one of the party Slept half the night." August 4, 1806, "Musquetoes excessively troublesom, so much so that the men complained that they could not work at their Skins and I find it entirely impossible to hunt in the bottoms, those insects being so noumerous and tormenting as to render it impossible for a man to continue in the timbered lands." August 5, 1806, "Musquetoes was so noumerous that I could not keep them off my gun long enough to take sight and by that means Missed." Numerous other references to the "very troublesom musquetoe" indicate that the Lewis and Clark Expedition considered the mosquito as one of the greatest drawbacks to the country through which they were traveling.

Mosquitoes are probably as abundant or even more abundant at present than they were in the days of Lewis and Clark. Reports are frequently sent to the office of the State Entomologist stating that livestock is kept in poor condition because it is pestered by mosquitoes, and more and more frequently are requests being received for aid in reducing the mosquitoes in the vicinity of towns and cities.

Acknowledgment is made of indebtedness to Mr. Frederick Knab of the United States National Museum, for the identification of specimens.

The State Entomologist has been able to give but little help in mosquito control work, primarily because the specific identity and the breeding habits of Montana mosquitoes were for the most part unknown, and, secondarily, because funds have never been available for securing such information nor for carrying out an experimental control program.

During the past three years, however, an attempt has been made to study mosquitoes as much as could be done without interfering with other branches of work already outlined. Members of the entomological staff have collected larvae and adults whenever possible, breeding places have been studied, and a few rearing experiments have been conducted. In this way considerable information and material have been collected and the purpose of this paper is to briefly discuss the more common species, which we have found within the State. It should be understood that no extended survey of the State has been attempted and that the species discussed were collected in a few widely separated localities.

MOSQUITOES OF THE GENUS AEDES

The great mass of the mosquitoes of Montana belong to species included by present-day workers in the genus Aedes. The general life history of the various species of Aedes mosquitoes as worked out by entomologists in other States is about as follows. The winter is passed in the egg stage. Snow water, spring or summer rains, or moisture from some other source causes the eggs to hatch at various intervals during the following season. The eggs do not necessarily all hatch at the first flooding, thus explaining why newly emerged mosquitoes may appear at subsequent floodings. Authorities state that the eggs of Aedes species never hatch the same year they are laid, but must be first subjected to the freezing of the winter season. The eggs are laid upon the ground. While the general outline of the life history is known, the details vary considerably in different species and in different localities. It is generally recognized that an accurate study of the life history of each species must be carried out in a locality before intelligent control work can be carried on.

Aedes curriei Coq.

This is the most abundant, the most widely distributed, and one of the worst biters of our Montana mosquitoes. In collections

of mosquitoes made in the river valleys and plains area a majority of the specimens collected will generally belong to this species.

Larval Records.—Our earliest seasonal record of larvae is May 6, and our latest August 22. This indicates that larvae are hatching from the eggs throughout the late spring and summer months whenever there is sufficient moisture to bring about hatching conditions.

The length of the larval period in eastern Montana was ascertained by Dr. R. R. Parker, in rearing experiments conducted in 1915. On July 16 an inch of rain fell, forming many temporary pools. Larvae collected from one of these pools on July 18 pupated on July 22 and emerged as adults July 25. On August 16 another heavy fall of rain occurred. Larvae collected August 22 from a pool formed by this rain pupated August 24 and emerged as adults August 27. Assuming that the eggs hatched within twenty-four hours after flooding, the larval period would be from five to seven days and the pupal period two to three days.

Larvae have been found in the following situations: "Irrigation water along roadside," "irrigation overflow," "temporary wayside pool," "permanent pool near railroad track," "pool connected with irrigating ditch," "irrigation water in alfalfa field," "temporary pool caused by summer rain."

Record of Adults.—The earliest seasonal record for adults is May 6 and the latest September 5. Specimens were taken on the latter date by H. L. Seamans at Whitehall even though there had been a severe frost the previous night. Adults were very abundant on this late date.

Adults have been found in the following situations: "On edge of slough," "in river bottom," "in town," "hotel porch," "alfalfa field," "damp place in willows," "blue-joint meadow," "sweet clover along railroad track," and in all manner of places.

The adults are voracious at all times except when forced into inactivity by low temperatures or high winds.

Distribution.—This species has been taken in the following localities: Harlem, Chinook, Turner, Miles City, Hardin, Laurel, Huntley, Bozeman, Three Forks, Lombard, Salesville, Dillon, Armstead, Cascade, and Judith Basin.

Aedes sylvestris Th.

Aedes sylvestris is second in importance only to *Aedes curriei.* It occurs in about the same localities, but in our collecting *sylvestris* has occurred in smaller numbers.

Larval Records.—The earliest seasonal record of larvae is May 19 and the latest August 22. The length of the larval stage is about the same as that of *A. curriei* and these two species have been taken repeatedly from the same pool.

Larvae have been found in the following situations: "Temporary pool in town," "pool formed by overflow of irrigation water," "small rather permanent pools," "waste irrigation water," "pool in edge of alfalfa field," "temporary pool caused by spring rains," "temporary roadside pool," "temporary pool caused by summer rains."

Record of Adults.—Our earliest seasonal record of adults is June 4 and our latest August 29. The adults are bad biters both day and night.

Adults have been found in practically the same situations as recorded for *A. curriei.*

Distribution.—This species has been taken in the following localities: Harlem, Chinook, Turner, Miles City, Forsyth, Billings, Laurel, Huntley, Hardin, Bozeman, Three Forks, Lombard, Dillon, Cascade and Florence.

Aedes nigromaculis Lud.

This species is a bad biter and occurs in abundance in some localities, but is not as widely distributed nor as abundant as the two species already discussed.

Larval Records.—The only records of larvae are as follows: "Temporary overflow from irrigation ditch," August 28; "temporary, muddy roadside pool," August 14; "temporary pool in town," August 8.

Record of Adults.—The first seasonal record of adults is June 4 and the last September 5.

Adults have been taken in the following situations: "Edge of slough," "grass above temporary pool," "alfalfa field," "along road," "prairie grass," "at light in towns," "blue-joint meadow," "river valley," "near stock yards," "in grass above pool which had dried out."

It has been noticed that this species is not as bad a biter in daylight as are *curriei* and *sylvestris*; toward nightfall, however, they become exceedingly ferocious.

Distribution.—This species has been collected in the following localities: Harlem, Miles City, Laurel, Big Timber, Cascade, Hardin, Huntley, Powderville, Bozeman, Three Forks, and the Judith Basin. It appears to be especially abundant in eastern Montana.

Aedes spencerii Th.

This species ranks fourth in importance among the species whicn we have collected.

Larval Records.—The earliest larval record is May 28 and the last June 28.

Larvae have been found in the following situations: "Water on edge of alfalfa field," "temporary pool caused by spring rains," "irrigation water in clover field."

Record of Adults.—The earliest seasonal record for adults is May 6 and the latest July 11.

Adults have been taken in the following situations: "Wild grass," "blue-joint field," "wheat field."

This species is a bad biter both day and night.

Distribution.—*Aedes spencerii* has been taken in the following localities: Cascade, Harlem, Turner, Hardin, Judith Basin, Three Forks, Huntley, and Bozeman.

Aedes pullatus Coq.

While this species has not been found in many parts of the State, it is extremely annoying in several of the higher mountain valleys.

Larval Records.—The only larvae of this species which we have found were taken June 13 in small pools found in tracks made by stock in marshy ground.

Record of Adults.—Taken in timber at high altitudes.

Distribution.—Warm Springs, July 1; Gallatin Mountains, June 30; Bridger Mountains, June 18. Further collecting in the higher parts of the State will probably show this species to be quite generally distributed.

Other Aedes Species

The following species of Aedes have been collected but not in numbers large enough to warrant considering them at present of

much economic importance: *A. campestris* D & R, *A. fletcheri* Coq., *A. stimulans* (group), *A. idahoensis* Th., *A. hirsuteron*, and *A. fuscus* O. S.

MOSQUITOES OF THE GENUS CULISETA

To this genus belong several species of Montana mosquitoes. Although they are biters, they seldom occur in such numbers as to be annoying. Unlike the Aedes, these species pass the winter as the adult and the eggs are laid directly in the water in more or less permanent pools.

We have collected Culiseta larvae in the following situations. "Cat-tail swamp," "alkali pool near swamp," "permanent swamp," "swamp along railroad," "irrigation overflow," "horse track filled with irrigation water."

Four species have been found, namely, *Culiseta inornatus* Williston, *C. incidens* Thompson, *C. inpatiens* Walker and *C. alaskaensis* Lind. The two most common species are *inpatiens* and *inornatus*.

MOSQUITOES OF THE GENUS CULEX

Only two species in this large group have been found in Montana, namely, *C. tarsalis* Coq. and *C. territans* Walk. Culex species are continuous breeders, that is, eggs are deposited directly in the water and hatch the same season. More or less permanent pools are the typical breeding places.

Culex tarsalis Coq.

This is by far the more abundant of the Culex species found in Montana.

Larval Records.—Our earliest seasonal record for larvae is June 22 and the latest August 28.

Larvae have been taken in the following situations: "Roadside pool," "small permanent pool," "cat-tail pool," "horse tracks in permanent swampy ground," "deep water in cat-tail swamp," "alkali pools near swamp," "permanent swamp along railroad," "water from irrigations," "pools formed by June rains in marshy ground."

Record of Adults.—Our only capture of adults was made by Dr. R. R. Parker at Laurel in 1914. In connection with a study of house-fly conditions, Hodge fly traps were placed so as to capture all the insects that escaped from the rear of a privy, the door of

which was usually open and the seats uncovered. Among the many insects captured during the month when the traps were in place, July 21 to August 21, were nine specimens of *Culiseta inornatus* and one hundred and thirty-seven specimens of *Culex tarsalis.*

We have no records of *C. tarsalis* taken while biting, although other writers state that they bite at night.

Distribution.—*C. tarsalis* has been taken in the following localities: Victor, Laurel, Yegen, Park City, Three Forks, and Hardin.

Culex territans Walk.

Our only record of this species is at Laurel where the larvae were taken in small permanent pools on August 25, 1914.

MOSQUITOES OF THE GENUS ANOPHELES

This genus is of interest because to it belong the species of mosquitoes which transmit malaria.

Anopheles occidentalis D & K

This is the only species which we have found in Montana and of this we have only three records, which are as follows: along creek, Missoula, June 24, 1914, by R. A. Cooley; in river bottom, Cascade, June 4, 1914, by J. R. Parker; in cabin, Powderville, April 21, 1916, by R. R. Parker.

THE STATE BOARD OF ENTOMOLOGY

The State Entomologist is by law the secretary of the State Board of Entomology, which is charged with the investigation and control of insects which transmit human and animal diseases. The membership of this board is all *ex officio* and all serve without compensation other than that received in their regular positions. The members of the board are the secretary of the State Board of Health (chairman), the State Veterinary Surgeon, and the State Entomologist.

The situation regarding the spotted fever tick will be discussed at length in the report of the Board of Entomology. The work has been continued with success during the past two years. In addition to the work in western Montana we have taken up a study of the tick and fever conditions in the eastern part of the State.

Further attention has been given to the study of the means of control of the house fly.

NEEDS AND PLANS FOR THE NEXT TWO YEARS

We have no plans for expansion of the activities of the State Entomologist's work other than to meet the actual demands made upon us. No two years are alike with respect to pests that become abundant and require attention and each year some new ones appear or come into prominence.

Most of the demands come either by letter or telegram. Many can be taken care of from the office after an examination of the specimens sent in, but in many cases it is necessary for some one to go to the town from which the complaint comes. It is often necessary to keep the insects alive in the insectary in order to study them and learn their identity and habits. Books and equipment are also necessary.

In all of these matters we cannot permit the research work conducted under Federal research funds to be interfered with. The two lines of work—research and State work—are entirely separate and we cannot use Federal funds for the State control work.

The following sums should be provided for the next two years:

	1917	1918
Salary of assistant	$900	$1050
Traveling and field expenses	1000	1000
Laboratory expenses	600	600
Equipment and supplies	300	350
Totals	$2800	$3000

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

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Third Annual Report of the State Grain Laboratory of Montana

BY

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Contents

Third Annual Report
Montana State Grain Laboratory

The Montana State Grain Laboratory, which was established by an act of the State Legislature of 1913, commenced work October 1st of that year. September 30, 1916, therefore closed the third year's work of the laboratory. This report presents a statement of the work carried on and the results obtained for this third year, namely, from October 1, 1915, to September 30, 1916.

THE YEAR'S WORK

The work of the laboratory during its third year consisted of:

1. Making purity and germination tests of the 5,035 samples sent in.
2. A study of the seed value of frosted wheat samples.
3. A continuation of the study begun in 1915 of hard seeds in clover samples.
4. A study of the germination of seeds at different periods after they have been harvested.
5. Cooperation with the Association of Official Seed Analysts of America in studies looking toward the standardization of grain laboratory methods.
6. A continuation of milling and baking studies of Montana wheats. The heavy demand for purity and germination tests made possible only a very limited amount of milling and baking work. Increased maintenance is needed so that this important work may be carried on actively.

OUTSTANDING FEATURES

In the year's work two features stand out prominently. These are the marked increase in the number of samples sent in for testing, and the striking increase in the weed-seed content of such seed as alfalfa, clover, timothy, and sweet clover.

Increased number of samples.—During 1913-14, the first year of its work, the laboratory received and tested 2,266 samples. In 1914-15, 2,570 samples were received, while during the year just closed 5,035 samples were reported on. This was an increase of

122 per cent over the work of 1913-14 and 99.4 per cent over that of 1914-15.

A comparison of the number of samples tested by the laboratories in other States with the number reported on by the Montana laboratory shows that the laboratory of this State handles more samples than that of any other State except Minnesota. This rapid increase over the work of previous years and the large amount of work asked of the Montana laboratory in comparison with those of other States suggests that many Montana farmers and seed dealers appreciate the importance of knowing definitely about the purity and quality of the seeds they are planting and handling. As the seed planted has an important bearing on the quality and value of the crop that will be harvested, the great increase in the number of growers and dealers who are asking information about the quality of their seeds is most encouraging and significant. It is hoped that substantial increase will be made in the number of samples sent in each year.

Increased weed-seed content.—Some very marked increases in the amount of certain weed seeds were found in some of the crop-seed samples examined. For instance, of the alfalfa seed samples examined in 1913-14, 7.6 per cent contained mustard seed. In 1914-15, 8.8 per cent and in 1915-16, 17.2 per cent of the alfalfa samples contained seed of this weed. The percentage of timothy samples containing mustard seed increased from 7 per cent in 1913-14 to 8.5 per cent in 1914-15 and to 22.2 per cent during the year just closed.

Russian thistle seed has been found present in an increasing number of samples. During 1913-14, 34.9 per cent of the alfalfa samples contained this weed. This increased to 45.6 per cent in 1914-15 and to 62.1 per cent in 1915-16. The seeds of this pest were also found in 34.5 per cent of the sweet clover samples examined in 1915-16, while it was present in only 5.3 per cent in 1913-14 and 15.7 per cent in 1914-15.

From the purity determinations it is evident that the number and variety of serious weeds are increasing in the State. A more complete presentation of data bearing on this point will be found in Table VIII.

The increase of weeds is the common experience as new lands are broken and large areas are used for grain-growing. The weeds

common in the communities increase and new ones are introduced with seeds brought in and planted. That this generally occurs ought not to be accepted as evidence that it is necessary. Newly broken lands are relatively free from weeds, and if clean seed is planted and weeds which appear are cut before they ripen seed, these pests may be kept under control. Farmers are urged to find out definitely the purity of the seed they are planting. Insist that this information be shown on the seed packages purchased. Seedsmen should see that the seeds which they offer to the public are free from serious weed pests. Send samples of seeds to the State Grain Laboratory at the Experiment Station, Bozeman, and a report on the purity and germination will be sent you promptly and without charge.

SOURCE OF THE SAMPLES

Table I shows the counties from which the different seed samples came. While the number of samples of the different kinds of seeds is greater in nearly every case than in the previous year, the most striking increase is in corn samples sent from Rosebud County. There is also substantial increase in corn samples coming from Custer County. In 1914-15 Rosebud sent 115 and Custer 210 corn samples, while in 1915-16, 830 samples were received from Rosebud and 327 from Custer. This striking increase from these two counties reminds us that the king of cereals in the Central West, corn, is rapidly establishing himself on the farms in the Treasure State. May his increase be rapid. He's our friend.

Table II shows the source—farmer or seed dealer—of some of the leading crop-seed samples tested during the past three years. There is an increase in the number of samples from both farmers and dealers each year but the greatest increase has been in the number received from farmers. In 1913-14 dealers sent in 40.8 per cent of the total number of samples and farmers 59.2 per cent. In 1914-15 the dealers sent in 39.1 per cent and the farmers 60.9 per cent, while in 1915-16 only 26.3 per cent of the samples were from dealers and 73.7 per cent were from farmers.

GERMINATION OF GRAINS AND GRASSES

Table III shows the average germination of the samples of the leading grains and grass seeds that have been tested during the past three years. Corn, oats, barley, and flax show a somewhat

TABLE I. SHOWING THE NUMBER OF SAMPLES OF THE DIFFERENT SEEDS RECEIVED FROM THE DIFFERENT COUNTIES

	Alfalfa	Barley	Alsike clover	Red clover	Sweet clover	White clover	Corn	Flax	Oats	Millet	Peas	Rye	Spelt	Timothy	Wheat	Vegetables	Grasses	Flowers	Identification and grade	Total
Beaverhead	2	2	..	..	..	..	1	..	2	..	1	3	..	..	21	1	1	..	..	34
Big Horn	2	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
Blaine	75	3	1	1	6	1	14	5	8	4	..	..	1	2	9	1	..	..	1	132
Broadwater	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	1	7
Carbon	6	..	..	2	2	..	8	..	6	..	..	..	..	..	9	..	..	..	1	34
Cascade	28	10	1	..	5	..	2	10	13	3	3	5	3	9	52	8	3	1	2	158
Choteau	6	2	..	1	..	..	4	..	6	..	2	..	..	2	8	30	..	..	1	62
Custer	18	2	..	..	5	..	327	3	16	7	2	4	1	1	22	1	..	..	4	413
Dawson	16	3	1	..	..	1	33	9	17	4	2	..	..	4	30	..	5	..	..	125
Deer Lodge	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fallon	..	..	..	..	..	..	51	..	1	3	..	..	..	..	..	..	..	..	..	55
Fergus	14	4	..	1	1	1	3	6	5	1	1	..	1	3	60	5	..	..	3	109
Flathead	12	5	..	5	1	1	1	..	7	..	4	1	..	10	7	2	1	..	..	57
Gallatin	37	21	3	8	2	5	26	6	37	..	57	2	..	12	56	120	5	28	62	487
Granite	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	2
Hill	6	9	..	..	2	1	24	13	15	9	1	7	3	4	22	1	7	..	4	128
Jefferson	2	..	..	..	..	..	..	..	4	..	..	2	..	..	1	..	..	..	1	10
Lewis & Clark	56	2	5	9	9	5	1	6	12	8	..	6	4	14	28	53	3	92	8	321
Lincoln	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	2
Madison	3	1	..	..	..	..	..	..	..	..	2	..	..	..	2	..	..	..	..	8
Meagher	..	5	..	..	..	..	6	..	4	..	..	3	..	4	26	..	..	..	2	50
Mineral	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Missoula	6	5	3	7	..	..	3	1	32	1	5	..	..	5	45	2	2	..	..	117
Musselshell	17	1	..	1	2	1	29	5	14	6	..	2	3	3	27	2	2	..	5	120
Park	6	19	4	2	..	..	..	..	24	4	9	2	..	10	31	1	3	..	..	115
Powell	..	1	..	..	..	1	..	..	3	..	..	..	..	..	2	..	1	..	..	8
Ravalli	1	1	1	2	..	..	4	..	4	..	11	..	..	4	1	..	..	..	1	30
Richland	4	1	..	..	1	..	2	5	2	..	..	..	..	..	10	..	1	..	..	26
Rosebud	34	2	1	..	6	..	830	8	12	4	..	1	1	3	23	..	2	..	3	930
Sanders	2	..	..	..	..	..	..	..	1	..	..	..	..	..	2	..	..	..	..	5
Sheridan	7	2	..	..	1	..	..	45	2	1	..	1	..	..	13	..	2	..	..	74
Silver Bow	..	3	..	..	..	..	..	..	1	..	..	9	..	..	5	..	..	..	7	25
Stillwater	1	2	1	..	..	..	3	1	7	..	..	..	..	1	7	..	..	..	4	27
Sweetgrass	1	2	..	..	..	..	..	..	1	1	..	..	..	..	7	..	1	..	..	13
Teton	5	5	1	1	1	1	1	9	10	..	2	..	2	8	19	12	..	..	7	84
Toole	..	..	..	..	2	..	..	1	3	..	..	..	..	..	1	..	..	..	..	7
Valley	5	2	..	..	2	..	20	14	19	3	..	..	..	..	27	..	2	..	3	97
Wibaux	..	..	..	..	..	..	1	2	..	..	..	..	..	..	..	..	..	..	..	3
Yellowstone	36	3	2	6	13	2	139	1	7	7	..	1	..	2	25	3	3	..	4	254
Unknown	1	..	..	..	2	..	9	..	2	1	..	..	..	1	3	3	..	..	2	24
Out of State	2	..	2	2	1	..	5	..	4	2	1	..	..	4	1	21	10	1	..	56

TABLE II. VARIETY AND SOURCE OF SAMPLES OF TEN MOST COMMON CROPS

Name of seed	1915-1916			1914-1915			1913-1914		
	Dealer	Farmer	Total	Dealer	Farmer	Total	Dealer	Farmer	Total
Alfalfa	171	242	413	281	229	510	235	304	539
Barley	36	81	117	35	44	79	45	58	103
Corn	139	1408	1547	62	456	518	106	106	212
Clover, alsike	18	8	26	13	10	23	12	7	19
Clover, red	36	12	48	40	30	70	26	32	58
Clover, sweet	29	37	66	11	32	43	8	48	56
Clover, white	10	10	20	5	2	7	9	1	10
Flax	38	112	150	38	55	93	28	128	156
Millet	36	33	69	12	19	31	31	15	46
Oats	71	230	301	77	106	183	67	193	260
Peas	67	36	103	27	21	48	62	26	88
Rye	22	22	44	7	2	9	30	8	38
Spelt	14	5	19	5	3	8	6	2	8
Timothy	75	34	109	34	33	67	37	62	99
Wheat	196	414	610	147	197	344	69	126	195
Total	958	2684	3642	794	1239	2033	771	1116	1887
Percentage of total..	26.3	73.7		39.1	60.9		40.8	59.2	

lower average germination for the year 1915-16 than for 1914-15. Except in the case of corn the lowering is not enough to be significant. The corn samples averaged below 80 per cent. This indicates the importance of carefully testing seed corn. The percentage here given is the average of 1,547 samples. Two hundred and twenty-one of these were below the Government standard, many of them being quite low. The germinating power of corn is apt to be injured by unfavorable weather conditions. Have your seed corn tested so you may know that the seed you are planting will grow.

GERMINATION OF ALFALFA AND CLOVER

Table IV shows the average germination of the alfalfa and clover seed samples tested during the past three years. The results given in this table show that a very small percentage fell below the Government standard of germination. Evidently the alfalfa and clover seed being grown in the State is of good quality.

GERMINATION OF VEGETABLE SEEDS

Table V shows the number of samples of vegetable seed received and the average percentage of germination. The Government standard of germination for the different kinds is also shown, where such

TABLE III. AVERAGE GERMINATION OF GRAINS AND GRASSES.

Name of seed	Number of samples	Average germination 1915-16 (per cent)	Average germination 1914-15 (per cent)	Average germination 1913-14 (per cent)	U. S. standard (per cent)	Number above standard (1915-16)	Number below standard (1915-16)
Corn	1547	79.89	92.59	90.68	85–90	1326	221
Wheat	581	93.29	94.39	90.63	90–95	489	92
Oats	288	88.06	91.45	82.57	90–95	489	92
Flax	150	94.05	98.06	97.59	....	....	....
Barley	117	85.82	93.01	89.21	90–95	67	50
Timothy	101	91.49	87.71	82.08	85–90	83	18
Peas	103	90.36	87.13	86.20	93–98	72	31
Millet	65	87.10	88.58	85.39	85–90	48	17
Rye	47	91.69	95.14	91.52	90–95	37	10
Brome grass	10	68.65	79.70	73.46	75–80	6	4
Rape	7	92.50	94.50	....	90–95	5	2
Sudan grass	14	73.77	73.42	....	....	....	....
Spelt	19	87.10	97.31	93.	....	....	....
Blue-grass	10	56.90	39.46	28.88	45–50	7	3
Rye-grass	8	42.87	46.62	43.50	....	....	....
Wheat grass	4	24.66	....	....	....	....	....
Vetch	3	93.25	67.90	71.39	....	....	....
Buckwheat	1	93.00	95.66	94.35	90–95	....	....
Orchard grass	3	71.50	55.50	....	....	....	....
Redtop	2	90.50	79.25	60.62	....	....	....

TABLE IV. AVERAGE GERMINATION OF ALFALA AND CLOVERS

Name of seed	Number of samples	Average germination 1915-16 (per cent)	Average germination 1914-15 (per cent)	Average germination 1913-14 (per cent)	Hard seed (per cent)	U. S. standard (per cent)	Number above standard (1915-16)	Number below standard (1915-16)
Alfalfa	382	89.11	89.58	90.53	21.67	85–90	344	38
Red clover	42	92.38	86.86	90.43	15.88	85–90	40	2
Sweet clover	62	85.72	76.09	78.83	43.12	....	....	....
Alsike clover	24	91.32	85.33	90.26	12.54	75–80	23	1
White clover	18	85.13	88.12	....	28.35	75–80	15	3

a standard has been set. This table shows that 214 samples of vegetable seed have been received and tested during the year. Except in the case of parsnips and carrots the tests show high average germination quality in most of the seeds.

TABLE V. AVERAGE GERMINATION OF VEGETABLE SEEDS, 1915-16.

Name of seed	Number of samples	Germination percentage	U. S. standard (per cent)	Number above standard	Number below standard
Asparagus	5	80.00	80–85	2	3
Beans	13	94.39	90–95	11	2
Brussels sprouts	3	76.16	....	....	....
Beets	14	76.60	....	....	....
Cabbage	25	80.66	90–95	8	17
Carrots	8	72.54	80–85	1	7
Cress	2	73.50	85–90	1	1
Cauliflower	9	79.61	....	....	....
Celery	8	69.	60–65	5	3
Cucumber	9	93.11	85–90	8	1
Chicory	3	54.33	....	....	....
Egg plant	3	65.70	75–80	1	2
Lettuce	8	96.43	85–90	8	0
Leek	4	74.12	....	....	....
Muskmelon	4	80.75	85–90	3	1
Onions	22	86.13	80–85	17	5
Parsnips	7	33.34	70–75	1	6
Pumpkins	4	92.50	85–90	4	0
Peppers	8	53.56	....	....	....
Parsley	3	57.33	70–75	....	3
Radish	11	86.13	90–95	5	6
Rutabagas	3	90.50	....	....	....
Squash	8	81.87	85–90	4	4
Tomatoes	13	88.	85–90	11	2
Turnips	6	91.50	90–95	5	1
Watermelon	11	88.88	85–90	8	3
Total	214				

PURITY OF GRAINS AND GRASS SEEDS

When we speak of seeds we refer to that small percentage of the crop that is planted in the soil and increases manyfold. We

expect the crop to be like the seed planted. If wheat seeds are planted we expect to harvest wheat; if oats, we look for returns in oats; if weeds, then weeds should be expected; and if a mixture of grain seeds and weeds, then we must expect to harvest a mixture of marketable grain and weeds. Such a mixture is less valuable than clean grain, since the amount of useless weed material will not be paid for by buyers and is of small value to the feeder. Furthermore, when grain is shipped, the weed seeds present are deducted as dockage from the total crop delivered, and the farmer receives nothing for this and has paid the freight on the pounds of useless material shipped. The grain growers of the Northwest lose annually millions of dollars in the reduction in the crop raised, in the cost of harvesting worthless material, and in the freight paid on material which returns nothing to the seller because of the weeds that are allowed to grow to maturity on so many farms. A study of the purity determinations of the seed samples sent to the grain laboratory during the past three years points out the percentage of waste which these weed offenders are causing.

Examination of Table VI shows that the tendency is for the impurities in seed samples to increase each year. In 1913-14 the average purity of the samples tested was 94.09 per cent, making the percentage of impurities present 5.91. In 1914-15 the average purity percentage was 93.68, leaving 6.32 per cent of impurities. In 1915-16 the purity average for all the samples was 91.7, leaving 8.3 per cent of impure material. These impurities include other kinds of crop seeds, weed seeds, and useless material such as dirt, chaff, etc.

The significance of 8.3 per cent of impurity in a crop may be appreciated if it is considered in connection with large grain shipments. Out of every 100,000 bushels of grain shipped from a particular locality, such a percentage of impurity would mean 8,300 bushels on which the producer would have to pay freight to the terminal but for which he would receive no return. This is practically six large carloads of waste material sent to the markets with every 100,000 bushels sold. Added to this loss is the harvesting and threshing charge for the 8,300 bushels. Altogether the impurities in many of the crops grown cause loss equal to a high rate of interest. Have your own seed tested and if it contains seeds of serious weed pests, do not plant it. Before buying clover, alfalfa, or other seed from dealers, get samples and send them to the grain

laboratory for testing. If the impurities present are serious, either in amount or kind, look elsewhere. Do not use impure seed.

TABLE VI. AVERAGE PURITY OF GRAINS AND GRASSES

Name of seed	Number of samples	Average purity 1915-16 (per cent)	Average purity 1914-15 (per cent)	Average purity 1913-14 (per cent)	U. S. standard (per cent)	Number above standard 1915-16	Number below standard 1915-16
Wheat	453	93.64	94.30	94.55	99	84	369
Oats	231	96.88	96.72	97.77	99	58	173
Flax	124	95.36	94.04	91.10	....	....	....
Barley	94	90.47	95.48	94.57	99	20	74
Timothy	99	95.18	97.56	96.05	98	45	54
Peas	....	....	98.26	98.31	99	....	....
Millet	48	95.56	97.62	95.73	99	10	38
Rye	24	90.45	95.26	92.20	99	1	23
Brome grass	11	87.96	88.04	87.90	90	5	6
Rape	2	99.11	98.60	....	....	....	....
Sudan grass	12	94.14	95.24	....	....	....	....
Spelt	18	94.62	94.27	95.06	....	....	....
Blue-grass	9	84.98	93.52	94.42	90	3	6
Rye-grass	6	92.04	96.93	91.51	....	....	....
Wheat grass	3	70.92	....	....	....	....	....
Vetch	1	96.22	96.90	97.25	....	....	....
Buckwheat	1	97.98	99.01	95.01	99	0	1
Orchard grass	1	86.72	64.65	....	....	....	....
Redtop	1	88.50	89.93	89.92	....	.	....
Average		91.70	93.68	94.07			

PURITY OF ALFALFA AND CLOVER SAMPLES

Table VII gives the number of samples examined during 1915-16 and the average purity of all alfalfa and clover samples tested during the three years 1913-14, 1914-15, and 1915-16. On the average the purity of the samples tested in 1915-16 was higher than that of those tested the two years previous. The average of all samples during the three years was considerably below the standard set for these seeds. While there is still room for much improvement, it is encouraging to note the general increase in the percentage of purity as each year's samples are tested.

TABLE VII. AVERAGE PURITY OF ALFALFA AND CLOVER

Name of seed	Number of samples	Average purity 1915-16 (per cent)	Average purity 1914-15 (per cent)	Average purity 1913-14 (per cent)	U. S. standard (per cent)	Number above standard 1915-16	Number below standard 1915-16
Alfalfa	376	93.64	94.81	89.97	98	151	225
Red clover	38	91.91	95.03	96.43	98	21	17
Sweet clover	58	96.67	87.34	78.15	....	....	....
Alsike clover	20	93.50	85.67	95.15	95	13	7
White clover	17	90.54	92.72	....	95	12	5
Average		93.23	91.11	89.88			

DISTRIBUTION OF WEED SEEDS

Table VIII gives the percentage of samples in which seeds of some of the most serious weeds have been found during the three years. Careful study of the table indicates that there is an alarming increase in the percentage of samples containing seeds of bad weeds. This means that the different weeds are being distributed over the State more completely each year. Reference has already been made to the seriousness of this spread of weeds. Farmers and seedsmen do well to give constant care to insure the use of clean seed.

SEED VALUE OF FROSTED WHEAT

Every year a rather large number of seed grain samples are sent in which clearly show injury from frost. In some of the samples the germination is very low, but in a large number the frost injury which is apparent on the seed covering has not injured the germinating power.

To find out something of the value of frosted kernels for seed, field tests were made to compare the producing power of frosted and unfrosted kernels. The results are shown in Table IX. The plan followed in getting kernels for this test was to use 32 wheat samples showing a large percentage of frosted kernels, that were sent to the laboratory for testing. Each sample was carefully divided into two parts, one containing only kernels showing frost injury and the other only kernels showing absolutely no frost injury. An equal number of frosted and unfrosted kernels were then planted

TABLE VIII. SHOWING THE PERCENTAGE OF THE SAMPLES EXAMINED IN WHICH SEEDS OF THE DIFFERENT WEEDS ARE FOUND

Common name	Botanical name	Alfalfa 1913	Alfalfa 1914	Alfalfa 1915	Red clover 1913	Red clover 1914	Red clover 1915	Sweet clover 1913	Sweet clover 1914	Sweet clover 1915	Timothy 1913	Timothy 1914	Timothy 1915
Dodder	Cuscuta spp.	11.02	14.	18.72	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mustard	Brassica spp.	7.60	8.80	17.16	7.68	6.80	10.52	10.52	18.78	3.44	7.	8.50	22.22
Lamb's-quarters	Chenopodium album	33.44	43.	76.96	53.76	44.20	65.79	57.86	40.60	81.03	26.	26.40	71.71
Russian thistle	Salsola pestifer	34.91	45.60	62.14	.....	8.50	21.04	5.26	15.65	34.48	.....	.....	.....
Sweet clover	Melilotus sp.	26.03	16.20	38.74	.....	.....	.....	.....	.....	.....	.....	.....	.....
Green foxtail	Chaetochloa viridis	21.38	22.40	32.24	42.24	25.50	44.73	5.26	12.52	10.32	.....	5.10	5.05
Pigweed	Aramanthus retroflexus	10.07	12.20	19.50	.....	.....	.....	15.78	9.39	13.76	5.	3.40	8.08
Curled dock	Rumex crispus	4.37	4.80	8.58	30.76	22.10	28.94	.....	12.52	22.36	7.	5.10	17.17
Plantain	Plantago sp.	5.70	4.	10.66	23.24	27.20	52.65	.....	.....	.....	.....	5.10	28.28
Gumweed	Grindelia squarrosa	15.58	12.	18.20	3.84	6.80	10.52	31.56	9.39	25.80	.....	3.40	15.15
Wild buckwheat	Polygonum convolvulus	.....	13.20	25.48	.....	5.10	18.41	5.26	9.39	22.43	.....	.....	.....
Ragweed	Ambrosia artemisiifolia	.....	.....	.....	5.76	6.80	21.04	.....	.....	.....	.....	.....	.....
Sheep sorrel	Rumex acetosella	.....	.....	.....	24.96	25.50	21.04	.....	.....	.....	8.	1.70	14.14
Smartweed	Polygonum persicaria	.....	.....	.....	3.84	3.40	18.42	.....	.....	.....	.....	.....	.....
Fanweed	Thlaspi arvense	.....	.....	.....	3.84	1.70	5.26	.....	.....	.....	.....	1.70	16.16
Sunflower	Helianthus sp.	.....	.....	.....	.....	.....	.....	26.30	15.65	22.36	.....	.....	.....
Wheat grass	Agropyron tenerum	.....	.....	.....	.....	.....	.....	31.56	3.13	34.40	.....	3.40	14.14
Five-finger	Potentilla sp.	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.	25.50	55.55
Peppergrass	Lepidium apetalum	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.	23.80	47.47
Shepherd's purse	Bursa bursa-pastoris	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.	5.10	42.42
Wild oat	Avena fatua	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
False flax	Camelina sativa	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.20	34.34
Cow cockle	Vaccaria vaccaria	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Roadside thistle	Carduus discolor	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corn cockle	Agrostemma githago	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Marsh elder	Iva xanthiifolia	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hare's-ear mustard	Conringia orientalis	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Yellow foxtail	Setaria glauca	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE VIII (Continued). SHOWING THE PERCENTAGE OF THE SAMPLES EXAMINED IN WHICH SEEDS OF THE DIFFERENT WEEDS ARE FOUND

Common name	Wheat 1913	Wheat 1914	Wheat 1915	Oats 1913	Oats 1914	Oats 1915	Barley 1913	Barley 1914	Barley 1915	Flax 1913	Flax 1914	Flax 1915	Millet 1913	Millet 1914	Millet 1915
Dodder	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mustard	1.12	8.64	13.46	7.14	12.92	18.92	4.12	3.33	17.02	22.62	25.96	28.80	11.35	18.20	33.28
Lamb's-quarters	5.60	3.84	13.46	9.24	16.32	17.63	8.24	3.32	19.14	11.70	8.26	30.40	18.60	13.65	33.28
Russian thistle	.56	1.96	4.18	....	.....	.....	.....	1.67	3.18	16.38	2.36	31.20	15.80	9.10	22.88
Sweet clover	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Green foxtail	....	.....	.....	.....	1.36	2.15	.....	.....	.....	3.12	3.54	8.	34.05	36.40	58.24
Pigweed	....	2.24	3.08	1.29	1.36	1.29	.....	.....	.....	7.02	7.08	14.40	6.81	9.10	16.64
Curled dock	....	.....	.....	1.29	1.36	2.58	.....	.....	.....	.....	.....	.....	.....	.....	.....
Plantain	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Gumweed	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Wild buckwheat	7.84	13.12	26.27	13.76	16.32	18.92	12.36	8.30	25.53	2.34	3.54	16.	4.54	13.65	8.32
Ragweed	....	.96	.88	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.08	18.20	10.40
Sheep sorrel	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....
Smartweed	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.27	9.10	18.72
Fanweed	....	1.92	3.52	1.72	4.08	2.15	2.06	1.67	5.31	.....	.....	.....	.....	.....	.....
Sunflower	3.92	4.80	7.94	7.14	16.32	11.62	2.06	.....	7.42	6.24	6.62	10.40	13.62	4.55	18.72
Wheat grass	1.12	1.92	4.84	3.44	2.04	6.45	.....	.....	.....	7.02	2.36	9.60	.....	.....	.....
Five-finger	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Peppergrass	....	.63	.66	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Shepherd's purse	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Wild oat	8.96	9.92	20.97	21.07	36.04	40.69	15.45	21.58	38.29	.....	1.18	8.	.....	4.55	6.24
False flax	.56	1.60	3.74	.....	4.08	2.58	1.03	1.67	2.12	24.96	20.50	26.40	.....	.....	.....
Cow cockle	3.92	8.64	17.21	4.30	10.20	8.27	.....	.....	.....	1.58	2.36	2.40	.....	4.55	6.24
Roadside thistle	....	.96	1.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corn cockle	1.12	2.88	.88	.....	2.04	1.29	.....	.....	.....	.....	.....	.....	.....	.....	.....
Marsh elder	....	.....	.....	.....	.....	.....	1.03	.....	7.42	.....	.....	.....	.....	.....	.....
Hare's-ear mustard	....	.....	.....	.....	.....	.....	.....	4.98	2.12	.....	.....	.....	.....	4.55	6.24
Yellow foxtail	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6.81	27.50	29.12

in rows side by side. This made 2 rows from each sample or 64 rows from the 32 wheat samples in the test.

The results as given in Table IX show a slightly lower field germination but a greater number of heads per row and a higher yield from the frosted kernels. The difference is not great enough to be very significant, yet it shows that kernels showing frost injury are not necessarily worthless for seed. It should be understood that grain may be entirely destroyed by frost, so far as its seed value is concerned, but this test suggests that all grain need not be discarded for seed purposes because it shows frost injury. The only safe plan is to have it tested before deciding either to use or to discard it.

TABLE IX. SEED VALUE OF FROSTED WHEAT

Condition of seed	Number of samples	Field germination (per cent)	Average number heads per row	Grain per row (grams)
Frosted	32	75	1525	1457
Unfrosted	32	78	1509	1375

GERMINATION OF GRAIN AT DIFFERENT PERIODS AFTER THRESHING

The question is sometimes asked whether grain is good for seed immediately after it is threshed. To find if this was the case a number of grains were tested in the fall of 1915 and again in the fall of 1916. In 1915, 7 samples of wheat, 5 of oats, and 4 of barley were collected from as many different fields immediately after threshing. Each lot was thoroughly mixed to secure uniformity and stored in a dry place in the laboratory. Samples were drawn from each of these lots at periods of 1 week, 1 month, and 2 months after threshing and tested under standard conditions for germination. In 1916, 26 samples of wheat were collected and tested in the same manner. The results of these tests are given in Table X.

The data presented show that immediately after threshing, wheat, oats, and barley show low germination. In practice this may have a bearing on the use of winter wheat for planting

immediately after it has been harvested. This practice is a rather common one, but from the tests here reported it would appear that the germination of newly threshed seed is slower than that of older seed. The data further point out that a low germination test on newly threshed grain does not necessarily mean that the grain may not have germination possibilities a few weeks later.

TABLE X. SHOWING THE GERMINATION OF SEED GRAIN AT DIFFERENT PERIODS AFTER THRESHING

	Winter wheat 1915	Winter wheat 1916	Spring wheat 1916	Oats 1915	Barley 1915
Number of tests	7	14	12	5	4
Germination 1 week after threshing (per cent)	53	8	18	15	66
Germination 1 month after threshing (per cent)	79	66	75	88	86
Germination 2 months after threshing (per cent)	96	99	90	96	95

WORK WITH THE ASSOCIATION OF OFFICIAL SEED ANALYSTS

During the past year the Montana laboratory has conducted some seed referee work in cooperation with the Association of Seed Analysts of North America. This organization is made up of representatives of the seed laboratory of the U. S. Department of Agriculture and of the State grain laboratories of the various States. The aim of the association is to work for the establishment of standard methods of sampling and testing seeds, for the adoption of a standard form of report on individual samples, and for the promotion of uniform State seed laws. Each year one laboratory is chosen as referee and a number of samples of several different varieties of seed most difficult to test are sent to the other laboratories in the association. In germination tests the Montana laboratory stood second among 34 laboratories reporting on 21 samples. The purity tests of timothy made by the Montana laboratory varied only one quarter of one per cent from the referee's findings.

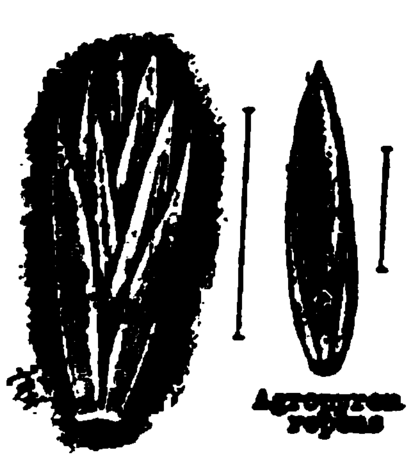
OUR WORST WEEDS*

In order that farmers and seedsmen may become familiar with the appearance of the seeds of some of the worst weeds, there are here presented illustrations of the seeds of twenty-one of the worst weeds, with a brief description of the seed and plant, and in some instances a summary of the percentage of samples in which the weed seeds were found. It is planned to issue a complete weed circular in the near future.

Carduus lanceolatus

Bull thistle (*Carduus lanceolatus*).

A large, coarse biennial,** 2 to 4 feet high, widely branching, growing in fence rows or waste places. Flowers purple, heads about 2 inches across. Seed similar to that of Canada thistle but larger, about 1-6 inch long, plumper in proportion to the length, generally darker at the broader end, grayish brown in color, marked with faint longitudinal lines. Bull thistle occurs occasionally in grain. It does not give much trouble, however, in well cultivated fields.



Agropyron repens

Quack-grass (*Agropyron repens*).

A perennial[†] having jointed, branching, underground rootstocks. A widely distributed, very injurious, and most persistent weed in all kinds of soil. Flower stems freely produced. Flowers in 3 to 7-flowered spikelets forming a narrow spike with the spikelets flat against the stalk. Leaves dark green, rather distinctly ribbed, and more or less hairy below. Seeds about 3/8 inch long. Kernel shaped like a small grain of wheat 3-16 inch long with wide-open groove. These seeds are a very common impurity in seeds of the coarser grasses. This plant is very similar to the common bluestem.

*The cuts used on the following pages were secured through the courtesy of Mr. F. H. Hillman, of the Seed Laboratory, U. S. Dept. of Agriculture.

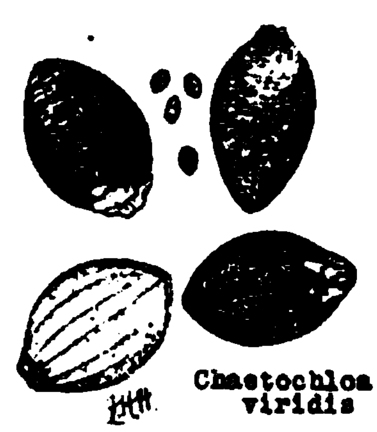
**A biennial is a plant requiring two seasons to complete its growth, the first being spent in collecting and storing up a supply of nourishment, which is used the second season in producing flowers and seeds.

†A perennial is a plant which continues to grow for many years.

Amaranthus retroflexus

Pigweed (*Aramanthus retroflexus*).

Annual* introduced from tropical America. A very common weed in all cultivated crops. Grows from ½ to 5 feet tall. Erect, growing from a long, fleshy, red tap-root. Leaves long, ovate, dull green, roughly hairy, prominent ribs and veins. Flowers very small, numerous, dense, crowded in thick compound spikes at the ends of the branches or in the axes of the leaves. The seed is round, lens-shaped, reddish to jet black. Pigweed is troublesome in root crops and gardens. In 1913-14 pigweed seed was found in 10.07 per cent and in 1915-16 in 19.5 per cent of the alfalfa samples examined.



Chaetochloa viridis

Green foxtail (*Chaetochloa viridis*).

A troublesome annual grass. Grows in bunches. Has a fibrous root system. Leaves 3 to 8 inches long, from ¼ to ½ inch wide. Seed color varies from yellow to purplish brown. The kernel is convex on one face and flattened on the other. Closely resembles the domesticated millets and belongs to the same family. Green foxtail is most commonly found in red clover, alfalfa, and millet.

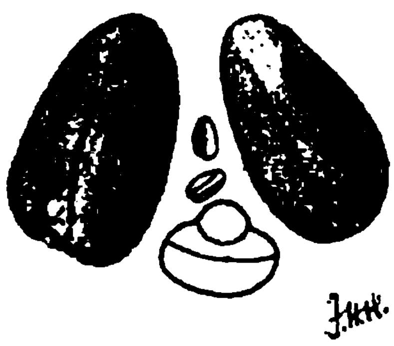
Lepidium apetalum

Peppergrass (*Lepidium apetalum*).

A native annual and winter annual,** very widely distributed but most abundant in light, sandy soils. Stems erect, branching above, 1 to 2 feet high. Stem leaves narrow at the base. Flowers minute, petals none. Seed pods 1-10 inch wide, heart-shaped, slightly longer than wide. Seed about 1-16 inch long, bright reddish yellow, egg-shaped in outline, much flattened. Both sides have a rather deep groove in the middle. Although there are but 2 seeds in a pod, each plant produces thousands of seeds.

*An annual is a plant which completes its growth in one year.

**Winter annuals are true annuals when the seeds germinate in the spring; but they are also biennial in habit, that is, their seeds ripen in the summer, fall to the ground, germinate and produce a certain growth before winter sets in, and then complete their development the next spring.


Camelina sativa

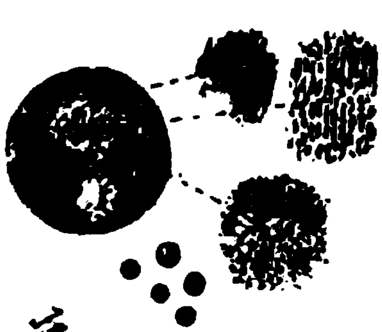
False flax (*Camelina sativa*).

Annual and winter annual. Both the large and small-seeded false flax are very common in flax. It is a member of the mustard family and has the usual characteristic—a high oil content which makes it possible for the seed to remain in the soil many years without losing its vitality. Produces large numbers of seeds. Plant erect, 18 inches to 3 feet tall, slender, smooth, branched at top, leaves lance-shaped, clasping the stem at the base. Flowers very small, yellow. Seeds borne in pear-shaped pods, 2-celled, resembling flax boll. Seed orange red, egg-shaped, flat, 1-20 of an inch long. False flax was found in 34.2 per cent of all timothy samples tested this past year, while the year previous it was found in only 10.2 per cent. Of all the flax samples examined in the past three years, 26.95 per cent have contained false flax.


Thlaspi arvense

Fanweed (*Thlaspi arvense*).

Annual and winter annual. In the higher, moister valleys this is one of the worst enemies of the western grain farmer. Grows from 4 inches to 2 feet tall, bright green, smooth, usually branched at top. Seed pods flat, fan-shaped, about ½ inch across, broadly winged at sides, notched at top, light green color at first, changing to an orange yellow as the plant matures. Each seed pod contains 4 to 16 seeds, of a deep reddish brown color, oval, flattened, roughened with fine curved ridges which run concentrically around a central groove. Fanweed is immensely prolific. Single plants have been known to produce as many as 16,000 seeds.


Brassica arvensis

Wild mustard (*Brassica arvensis*).

Annual. A very noxious weed in grain fields. A single plant will produce an immense number of seeds, sometimes as many as 15,000. Because of the high oil content these seeds may remain buried in the soil for a long time without losing their vitality. The plant grows erect from 1 to 3 feet tall, branching at the top, rough with short, stiff hairs. Purplish red markings at the junction of the branches with

the stem are a marked characteristic. The seeds are round, about 1-16 inch in diameter, brown or reddish black, appear slightly pitted or netted under a glass, and have a decidedly pungent taste. During the past three years mustard increased from 7.6 to 17.16 per cent in the alfalfa samples examined, from 7 to 22.22 per cent in the timothy, from 11 to 33 per cent in the millet, and from 1.12 to 12.8 per cent in the wheat.

Cuscuta arvensis

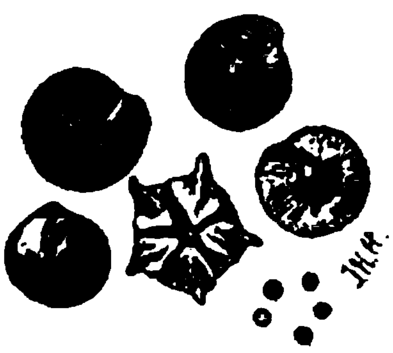
Dodder (*Cuscuta* spp.).

Annual. A parasite with slender, yellowish stems which wind themselves about the host plant and, after developing wart-like suckers which become attached to the stems, break off at the ground and obtain nourishment thereafter from the host plant. The seeds are very small, rounded, oval, grayish or yellowish brown. As yet dodder has not given a great deal of trouble, but experiences in other States have led us to believe that care should be taken not to use seed infested with this weed. In alfalfa seed, dodder has increased steadily the last three years. In 1913-14 it was found in 11.02 per cent of the samples; in 1914-15, in 11 per cent; and in 1915-16, in 18.72 per cent.

Salsola pestifer

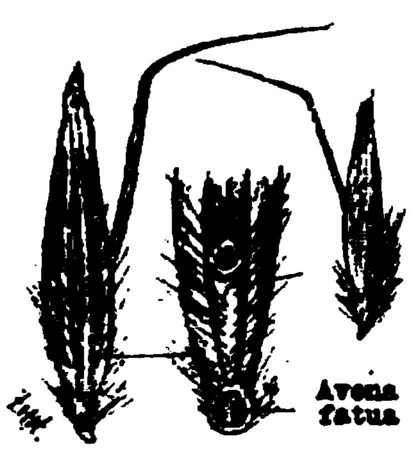
Russian thistle (*Salsola pestifer*).

A large, bushy, succulent annual, introduced from Russia. The flowers are very tiny and inconspicuous. In the mature plant the stems become hard and woody, ridged and streaked with red lines. Russian thistle thrives in dry soil—places where moisture is most needed by other plants. The mature plant when broken from its root is tumbled along for many miles by the wind, scattering its seed as it goes. A single plant is said to bear from 10,000 to 100,000 seeds which will retain their vitality in the soil for several seasons. The increase of Russian thistle is shown by the fact that in 1913-14 only 34.9 per cent of the alfalfa samples contained it, while in 1915-16 it was found in 62.1 per cent. The Russian thistle is not a true thistle and has little resemblance to the Canada thistle and the bull thistle.


Chenopodium album

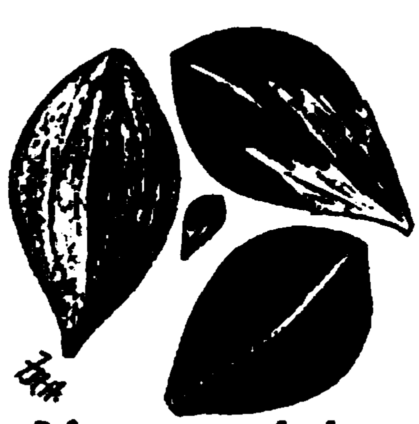
Lamb's-quarters (*Chenopodium album*).

Annual. Introduced from Europe. Probably the most common weed in the State. "A succulent, swift growing weed, which rapidly absorbs the food and moisture needed by the crop among which it intrudes." Two to six feet tall, slender, erect, much branched, pale green coarsely toothed leaves. Seed about 1-20 inch in diameter, lens-shaped, circular in outline, shiny black. Lamb's-quarters is increasing very rapidly in all crop seed. In 1913-14 it was found in 33.4 per cent and in 1915-16 in 76.9 per cent of the alfalfa samples. Like increases were found in red clover, sweet clover, timothy, and flax.


Avena fatua

Wild oat (*Avena fatua*).

An annual introduced from Europe. Thrives best under field conditions suitable for growing grain. Seeds mature early and shatter easily when ripened. Wild oats are similar in shape to cultivated oats but can be distinguished by the horeshoe-shaped scar at the base, the stiff hairs which surround it, and the twisted awn. The color is usually dark gray or brown. In 1913-14, 21 per cent of the oats tested at the State Grain Laboratory contained wild oats, and in 1915-16, 40.69 per cent contained wild oats. In 1913-14, 8.9 per cent of the wheat samples, and in 1915-16, 19.9 per cent were infested with wild oats.


Polygonum convolvulus

Wild buckwheat (*Polygonum convolvulus*).

Annual. Introduced from Europe. A twining vine, with angular, branching stems, and thin, smooth, arrow-shaped leaves. A special nuisance in grain fields. Seeds begin to ripen and drop to the ground before harvest. The seed is dull black, triangular, about ⅛ inch long. Often found with the outer coat broken away, leaving the seed a pearly white color with rounded angular corners. Wild buckwheat was found in 7.84 per cent of the wheat in 1913-14 and in 25.6 per cent in 1915-16. The percentage of barley

samples containing this weed was 12.4 in 1913-14 and 25.3 in 1915-16, while in flax samples it was found that only 2.3 per cent contained this weed in 1913-14 and that 16 per cent contained it in 1915-16. Wild buckwheat is listed as one of the inseparable impurities in the 1916 Minnesota grades and when present in sufficient quantities in wheat the grade is lowered.


Carduus arvensis

Canada thistle (*Carduus arvensis*).

A common and very troublesome perennial with deep running rootstocks. Stems 2 to 4 feet high. Leaves waved and crested, without stalks, very prickly. Flower heads numerous and arranged in a flat or convex cluster with branches arising at different levels and with the progression of blooms from the margin inward. Flowers variable in color, ranging from a pale purple to shades of pink and white. Seed ⅛ inch long, light brown, elongated oblong, smooth, somewhat flattened and curved, more or less bluntly angled, marked with faint longitudinal lines; the top nearly round, flat, and with a narrow rim with a small cone-shaped point in the center. Canada thistle differs from other thistles in that it grows in very dense masses, spreading out from year to year, killing out all other vegetation in its pathway.


Rumex crispus

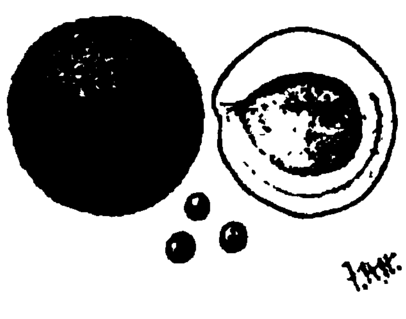
Curled dock (*Rumex crispus*).

A well known weed, very common in alfalfa and clover. A perennial with a deep tap-root. Propagates by seeds. Stems erect, 2 to 3 feet, smooth. Basal leaves oblong-lance-shaped in outline, 6 to 12 inches long, with wavy margins. Stem leaves on short stalks and much smaller or absent towards the top of the stems. Seeds 1-12 inch long, both ends pointed, widest near the center with edges very slightly margined, reddish brown and very shiny. Curled dock was found in 4.4 per cent of the alfalfa samples in 1913-14 and in 8.58 per cent in 1915-16. It has been found in an increasing percentage of the red clover, sweet clover, and timothy samples each year.

Bursa bursa-pastoris

Shepherd's purse (*Bursa bursa-pastoris*).

Annual and winter annual. Member of mustard family. Much variation in size and appearance, growing from 3 inches to 2 feet tall. Sometimes a rosette of leaves at the base. Varies from a bright green to a grayish yellow color. Upper leaves arrow-shaped, the basal lobes clasping the stalks. Flowers small, with four white petals. Seed pod flat, triangular or wedge-shaped, notched at the top, outer edges rounded. Each pod contains 12 to 20 seeds 1-24 inch long, oblong, reddish or yellowish brown. Shepherd's purse is one of the most common weeds in the State, though it is not regarded as a difficult weed to eradicate. It has increased in timothy seed, being found in 2 per cent of the samples in 1913-14 and in 42.42 per cent in 1915-16.



Vaccaria vaccaria

Cow cockle (*Vaccaria vaccaria*).

An annual introduced from Europe. One to three feet tall, many-branched, smooth, rounded at joints. Leaves long ovate, pointed, smooth. Flowers in loose clusters, pale pink, with 5 petals. Seeds from 20 to 30 in a pod, round, dull black, minutely roughened surface. Cow cockle is very objectionable in milling wheat and when present in sufficient quantity reduces the grade materially. It has increased in seed wheat, being found in 3.9 per cent of the samples in 1913-14 and in 17.2 per cent in 1915-16.

Grindelia squarrosa

Gumweed (*Grindelia squarrosa*).

A very common weed in the West. Plant smooth, erect, somewhat reddish in color, growing from 5 inches to 2 feet tall. Flowers daisy-like, golden yellow, the heads about an inch across and very sticky. Seeds creamy white or light brown, very variable in appearance; more or less flattened, often 4-angled, straight to much curved, narrowed at the base, distinct marginal rim, some smooth, others finely grooved or ridged lengthwise.

Rumex acetosella

Sheep sorrel (*Rumex acetosella*).

Perennial introduced from Europe. Very persistent. Spread by underground fleshy rootstocks. Has slender, reddish, branching stems. Grows from 5 inches to 1½ feet tall. Leaves fleshy, the upper ones rather lance-shaped, the lower arrow-shaped, smooth, silvery. Seeds closely covered by a dull, reddish brown, roughened calyx or husk. When this is removed the seeds are shiny with three equal sides, broadly oval, the base rounded, apex abruptly pointed, sides convex, reddish brown or amber color.

Helianthus annuus

Wild sunflower (*Helianthus annuus*).

Annual. Very common in grain fields, their bright yellow flowers making them very conspicuous. Stems 1 to 4 feet high, stout, woody, simple or sparingly branched, rough or hairy. Seeds about 1-6 inch long, brown, variable in shape but mostly narrowly oblong, egg-shaped in outline, flattened and rather angular, grooved lengthwise, cross-mottled with irregular, zigzag white lines. Heads 1 to 3 inches across with many light yellow sterile rays, centers dark purple or brown. Leaves thick, ridged and rough, 1 to 5 inches in length, broadly oval, pointed, three-ribbed, rough on both sides, with stout, hairy stalks.

Iva xanthiifolia

Marsh elder (*Iva xanthiifolia*).

An annual with stems stout, woody and almost shrub-like, much branched, 3 to 8 feet tall. Lower part of the plant is smooth, but the upper leaves and branches are roughened with minute hairs. Leaves mostly opposite, broadly ovate, coarsely and very irregularly toothed, three-ribbed, narrowed abruptly to a stiff stalk. Heads small and greenish, closely crowded to the branchlets. Seeds usually 5 in each head, about ⅛ inch long, ovoid, slightly flattened, varying in color from light brown to nearly black.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

BULLETIN NO. 114 DECEMBER, 1916

Report of the Work of the Horticultural Substation

An early picture of the buildings upon the horticultural substation grounds. Ornamental trees and shrubs have since been planted about the buildings.

BY
O. B. WHIPPLE
Horticulturist

A Report of the Work of the Horticultural Substation

The Tenth Legislative Assembly in February, 1907, authorized the executive board of the Montana Agricultural College to establish a substation for the purpose of carrying on experimental work in horticulture, the station to be located at such point in the State as the board might select. This action grew out of a demand on the part of practical fruit-growers of western Montana for experimental data that would fit their conditions, and a realization on the part of those connected with the Experiment Station that it was hopeless to try to solve the fruit-growing problems of the State in general by experiments conducted at the home station. Climatic variations are, if anything, more significant in horticulture than in other lines of agricultural work and it is safe to say that in most States traversed by important mountain ranges there is a real need for the establishment of horticultural substations.

During the summer of 1907 twenty acres of land was selected in the Bitter Root Valley about one mile north and one mile east of Corvallis. The land was donated by the Bitter Root Valley Irrigation Company and was selected as being typical of much of the bench land of the valley then being planted to fruit trees. The locality was chosen because its climate was fairly representative of that of many of the valleys west of the continental divide while very much unlike that of the mountain valleys east of the divide, in one of which the home station is located. The winters are milder than in eastern Montana, at least not so trying upon fruit trees, and this is an important factor in fruit growing.

The weather records in Table I were taken at Hamilton, which is about seven miles south of the substation. More complete data may be found in Bulletin No. 99, "A Report on Montana Climate," and its appendix, "Temperature Records."

The substation is now well equipped with buildings, machinery, and bearing trees, so that progress in the future will be more rapid. The buildings include a cottage costing $1,800; a barn, $1,500; a tool shed and storage cellar, $300; and a packing shed and implement

TABLE I. WEATHER RECORD FROM 1903 TO 1913 INCLUSIVE

Year	Minimum temperature (degrees)	Annual precipitation (inches)	Last killing frost	First killing frost
1903	-2	8.77	May 22	Sept. 14
1904	8	7.74	May 25	Oct. 5
1905	-28	7.69	May 18	Oct. 9
1906	-13	15.78	May 6	Sept. 15
1907	-18	13.68	May 5	Sept. 18
1908	-9	13.48	Apr. 30	Sept. 26
1909	-33	16.58	May 8	Sept. 23
1910	-23	14.95	June 3	Aug. 24
1911	-26	14.11	May 28	Sept. 24
1912	-12	13.29	May 3	Sept. 14
1913	-22	9.27	May 1	Sept. 24

shed, $300. The grounds were also fenced at a cost of $150 to $200. The horses and machinery have cost about $1,200. Thus the total investment by the State is about $5,200. The land which was donated is worth at least $6,000.

In the spring of 1908 the work of the horticultural substation was inaugurated with the planting of ten acres of orchard. Five acres of this planting was to be devoted to a test of orchard-culture methods and five acres to a test of commercial varieties of fruit. In 1909 the plantings were increased by adding approximately one acre to the variety-test tract. In 1912 a third project was started with the planting of four acres of orchard to be devoted to a test of stocks upon which to top-graft varieties of apples. The orchard plantings at the present time cover fifteen acres.

In every orchard community the question of methods of orchard tillage sooner or later becomes a serious problem, especially when viewed from the standpoint of maintaining soil fertility. The project on tillage methods was early outlined in the hope of answering some of the questions arising under Montana conditions before the tillage situation became serious. At the present time we feel that this is one of the most important problems of the fruit-growers

of the community. We also feel that the progress made upon this project merits publication and that the conclusions drawn are well worth the careful consideration of every fruit-grower of Montana.

In each new fruit-growing community some one must do a certain amount of pioneering in the way of variety testing. Much of this work had been done by the early fruit-growers previous to the establishing of this substation and to these pioneers credit is due. But in 1908 we believed and in 1916 we still think that further work along the line of variety testing is desirable. Varieties, more especially of apples, may yet be found which, on account of their adaptability to our climate, will more firmly establish the reputation of western Montana as a fruit-growing region than is possible with the varieties now being grown.

It is yet too early to report progress on the third project but we feel that this, too, will yield results of practical value to the fruit growers of the community. It has a direct relationship to problems of soil fertility.

ORCHARD CULTURE TESTS

The five-acre tract devoted to tillage experiments was planted to four varieties of apples—McIntosh, Wealthy, Rome (Beauty), and Alexander. There were four rows of each variety running lengthwise of the tract, which was subdivided crosswise into five one-acre plots designated as 1, 2, 3, 4, and 5. Plot 1 was to be intercropped with potatoes; plot 2 was to be planted to clover with all the growth left upon the ground; plot 3 was to be planted to clover and all growth cut and removed; plot 4 was to be planted to field peas, the growth to be left on the ground and plowed under; and plot 5 was to receive continuous clean cultivation. With the progress of the work it was found desirable to make some slight modifications in the plans. From the standpoint of weed control it was found desirable to give all plots clean cultivation one year out of each three. On account of the size of the trees and consequently the limited area available for planting a tilled crop, it was found impractical to grow potatoes on plot 1 after the season of 1913. Beginning with the season of 1915 it was planned to use this plot in testing alfalfa as a crop for the orchard. Unfortunately the trees of the varieties Alexander and Wealthy have been destroyed

by blight. The variety Arkansas (Black Twig) was planted in 1914 to replace the Alexander removed in 1913. Wealthy trees destroyed by blight were replaced in 1915 by the same variety budded well above the surface of the ground on Delicious root systems. While this necessary replanting reduced the number of trees from which the data shown in Table II were obtained, the replanting of young trees has given an opportunity to better observe the behavior of both young and bearing trees under the various systems of tillage. The data in this table are also limited in so far as yields of fruit are concerned. The crop of 1914 was almost a total failure on account of blossom blight and the crop of 1916 was lost by late spring frost. These data are not presented with the idea of showing which system of tillage is best; they do not cover a sufficiently long period. As a matter of fact plots 2 and 4 have

TABLE II. SHOWING YIELD AND GROWTH OF TREES IN ORCHARD-CULTURE TESTS

Variety	Plot	Yield per tree (pounds) 1912	1913	1915	Average	Average growth Diameter (inches)	Height (feet)
McIntosh	1	7.00	19.00	71.00	15.66	5.03	12.02
Rome (Beauty)	1	5.25	6.50	10.50	7.41	4.28	12.09
Average					11.53	4.65	12.05
McIntosh	2	2.50	37.00	40.00	26.50	4.85	12.05
Rome (Beauty)	2	4.20	5.00	15.75	8.31	4.11	11.73
Average					17.40	4.48	11.89
McIntosh	3	2.75	10.50	43.50	18.91	4.35	11.58
Rome (Beauty)	3	3.00	6.00	6.30	5.10	3.86	11.31
Average					12.00	4.10	11.44
McIntosh	4	3.50	28.00	62.00	31.16	3.94	10.20
Rome (Beauty)	4	4.30	4.50	6.50	5.10	3.87	10.85
Average					18.13	3.90	10.52
McIntosh	5	2.00	19.00	27.50	16.16	4.14	9.95
Rome (Beauty)	5	1.00	3.25	4.00	2.75	3.83	10.26
Average					9.45	3.98	10.10

given the highest yield of fruit and plot 5 the lowest. This would apparently indicate that the growing of clover or peas in the orchard has been beneficial. The data really show that there has been thus far no great variation in growth or fruit production between the different plots. Young trees on plots 1 and 5 have usually made the best growth. We have observed that clover and peas usually checked the growth of young trees and we are inclined to attribute this check to their drawing heavily upon the available nitrogen during the early part of the growing season. During the seasons when clover and peas have occupied the space between the trees, the foliage upon the young trees has been lighter in color and smaller than that of the young trees upon the cultivated plots. Had this check in growth been due to drier soil conditions, the leaves might still have been smaller but they would have been dark green.

TREATMENT OF PLOTS IN ORCHARD-CULTURE TESTS

Plot 1

1908 Planted to potatoes.
1909 Planted to potatoes.
1910 Clean cultivation.
1911 Planted to potatoes.
1912 Planted to potatoes.
1913 Planted to potatoes.
1914 Clean cultivation.
1915 Seeded to alfalfa June 1st. Good stand secured and plowed under in September when about one foot high.
1916 Clean cultivation.

Plot 2

1908 Clean cultivation.
1909 Seeded to clover but poor stand secured; growth clipped once and left on ground.
1910 Clover plowed under in early spring and plot cultivated during the season.
1911 Seeded to clover May 20th. Cut once and left on ground.
1912 In clover. One crop cut and left on ground. Second crop plowed under in late August.
1913 Clean cultivation.
1914 Seeded to clover late in May. Clipped once and left on ground.
1915 In clover. First crop cut and left on ground. Second crop plowed under early in September.
1916 Clean cultivation.

Plot 3

1908 Clean cultivation.
1909 Seeded to clover but poor stand secured. One crop cut and removed.
1910 Clover plowed under in spring and plot cultivated during the season.
1911 Seeded to clover May 20th. One crop cut and removed.
1912 In clover. Two crops cut and removed. Plowed late in August.
1913 Clean cultivation.
1914 Seeded to clover in late May. One crop cut and removed.
1915 In clover. Two crops cut and removed. Plowed in September.
1916 Clean cultivation.

Plot 4

1908 Clean cultivation.
1909 Seeded to peas June 10th.
1910 Growth of 1909 plowed under in spring and plot cultivated during the season.
1911 Planted to peas May 15th.
1912 Growth of 1911 plowed under in the early spring. Again planted to peas May 23d and crop plowed under August 22d.
1913 Clean cultivation.
1914 Planted to peas late in May and crop plowed under in early September.
1915 Planted to peas June 1st and crop plowed under in early September.
1916 Clean cultivation.

Plot 5

Continuous clean cultivation during seasons of 1908-1916 inclusive.

The data presented in Table III are furnished by the station chemist and show a decided variation in the nitrogen content of the soils of the different plots. Each sample is a composite of five borings from different parts of each plot. The nitrogen content per acre-foot of soil is calculated upon an estimated weight of 3,500,000 pounds per acre-foot of soil. While the variation in nitrogen-content expressed in percentage may mean little to some of us, we can better appreciate the difference when set down in pounds of nitrogen per acre-foot of soil. As shown by the table, plot 2 contains 3,019 pounds of nitrogen in the first two feet of soil, while plot 5 has only 1,514 pounds, or a variation of 1,505 pounds. The comparison may mean still more with the variation stated in terms of a common nitrogenous fertilizer. To bring the nitrogen-content of plot 5 up to that of plot 2 would require the application of approximately 9,406 pounds of commercial nitrate of soda per acre.

TABLE III. ANALYSIS OF SOIL FROM ORCHARD CULTURE TRACT

				Analysis of fine earth only			
Plot	Foot	Gravel (per cent)	Fine earth (per cent)	Nitrogen (N) (per cent)	Lime (CaO) (per cent)	Phosphorus pentoxide (P_2O_5) (per cent)	Nitrogen per acre-foot of soil (pounds)
1	1st	36.4	63.6	0.052	1.62	0.095	1157
1	2nd	43.8	56.2	.048	6.92	.095	944
2	1st	21.5	78.5	.072	1.18	.064	1978
2	2nd	49.6	50.4	.059	9.10	.103	1041
3	1st	37.6	62.4	.064	1.82	.076	1397
3	2nd	50.0	50.0	.044	8.64	.115	770
4	1st	36.3	63.7	.073	1.31	.048	1627
4	2nd	60.4	39.6	.054	7.86	.079	748
5	1st	25.4	74.6	.039	.95	.079	1018
5	2nd	43.3	56.7	.025	3.90	.127	496

Note.—The method adopted by the Association of Official Agricultural Chemists was used in analyzing the above samples. The samples were taken in late August, 1916, when all plots were under clean cultivation.

But after presenting these data on growth and nitrogen-content, we can best illustrate the danger of clean cultivation in the orchard with photographs of trees from clean-cultivated plots and from plots on which clover has been grown. The trees pictured in figures 2, 4, 5, 6, and 7 all show an abnormal growth which has become quite generally known to local fruit-growers as winter-injury. Practically all the trees on plot 5 have some of these limbs without foliage. A few trees on plot 1 show the same bare limbs. Many trees in the variety-test tract which has been under clean cultivation eight out of nine seasons show the same abnormal growth. Some cases are similar to figure 6, a condition often referred to as rosette, and others are more seriously affected like figures 4 and 5. Upon close examination these limbs do not resemble winter-killed limbs. The limbs on the trees shown in figures 4 and 5 are all alive and practically all of them bear some foliage. In September, when these photographs were taken, winter-injured limbs would have been, in most cases, entirely dead and shriveled. This so-called winter-injury is quite common throughout the valley where clean cultivation has

FIG. 1. The first six trees a typical row of McIntosh on plot 2.

FIG. 2. The first five trees a typical row of McIntosh on plot 5.

FIG. 3. A typical McIntosh tree on plot 2.

FIG. 4. A typical McIntosh tree on plot 5.

FIG. 5. A King David tree on plot 1 where the nitrogen-content of the soil is also low.

FIG. 6. A Northern Spy tree in the clean cultivated variety-test tract.

FIG. 7. A very severe case of so-called winter-injury.

been the general practice in growing young orchards. In the orchard-culture tract, trees on plots 2, 3, and 4 do not carry any of these abnormal limbs. They are all making the normal, healthy growth pictured in figures 1 and 3. This lends further evidence that the trouble is not the result of winter freezing. We believe the real cause is a deficiency in available plant food, probably nitrogen. Many analyses of soils from the valley, made by the station chemist, have shown a nitrogen-content as low or lower than that of plot 5, and many of these soils are producing trees similar to those shown in figures 2, 4, 5, 6, and 7. Analyses also indicate that some of these soils are probably deficient in phosphorus. While the addition of organic matter from growing cover crops will no doubt increase the availability of the phosphorus present, the time may come when this element of plant food will need to be replenished by applications of commercial fertilizer. We do not say there are no instances of trees winter-killing, there are many of them, but we do feel that the loss of apple trees resulting from a lack of available plant food is far greater than the loss from winter-killing.

While this experiment is as yet incomplete, we feel that some lessons may be drawn from it. First, our soils are not inexhaustible and the fruit-grower cannot hope to long maintain a thrifty orchard, on most soils, without resorting to some means of replenishing the supply of available plant food. Second, we believe we have demonstrated that this can be done by growing leguminous cover crops to be plowed under. In these tests clover handled as on plot 2 has given very good results and it has been a cheaper method of orchard tillage than clean cultivation. The results on plot 3 suggest that the removal of clover hay from the orchard is not a serious drain upon the fertility of the soil. During the second season the first crop at least might be removed for hay. The experience with field peas has shown this also to be an effective way of maintaining the fertility of the orchard soil. Weeds were more troublesome than on clover plots, however. In growing field peas it might be better to plant the peas and clean-cultivate in alternate years. But the important lesson is that we should prepare to face at once the question of maintaining the fertility of our orchard soils. If our young orchards are not now suffering, we still should begin to build for the future when heavy crops of fruit will draw heavily upon the soil.

Where trees are in the condition of those shown in figures 2, 4, and 6, it may be desirable to employ some quicker means of increasing the nitrogen-content than the growing of leguminous cover crops. A good application of manure would no doubt stimulate these trees by furnishing a temporary supply of nitrogen. If manure is not plentiful, it may be spread about the trees in a circle a little larger than the spread of the branches. Two pounds of nitrate of soda spread about such trees early in April would also furnish temporary relief. This should be spread over the same area of ground as suggested for the manure and cultivated or hoed into the soil.

VARIETY TESTS

APPLES

In the spring of 1908 the following twenty-nine varieties of apples were planted:

Akin	Marshall	Sierra Beauty
Alexander	McIntosh	Stayman Winesap
Bismarck	Newtown Spitzenburg	Vandevere
Arkansas (Black Twig)	Northern Spy	Vanderpool Red
British Columbia	Ontario	Wagener
Coos River Beauty	Opalescent	Wealthy
Fallawater	Orenco	Winter Banana
Jonathan	Palouse	Winterstein
King David	Rome (Beauty)	Wismer Desert
Lawver (Delaware Red)		Yellow Newtown

With the exception of Alexander, McIntosh, Rome and Wealthy, which were planted in blocks of a little over an acre each, and King David, only two trees of which were under test, the varieties were tested in blocks of ten trees each. Replants were made in case of loss and the full number of trees maintained until the first trees reached a bearing age. In the spring of 1909 the following additional varieties were planted:

Ben Hur	Florence (Crab)	Summer Champion
Boiken	Henry Clay	Summer Queen
Dartmouth (Crab)	Lowland Raspberry	Red June (Wilson)
Delicious	Oliver (Senator)	Yellowstone Pippin

With the exception of Delicious and Yellowstone Pippin which were planted in blocks of ten, the plantings of 1909 were of one or two trees of each variety.

Since 1909 something over twenty new plantings have been made, either of new varieties or of varieties previously planted in numbers too small for a fair test. We have practiced planting since 1909 in blocks of not less than five trees and in most cases ten.

The plantings of 1908 and 1909 have in the majority of cases borne some fruit. In many cases varieties have shown themselves so poorly adapted to the locality or so susceptible to disease that it seems safe and wise to mention them and caution growers about planting them. It is well to remember that so far as blight is concerned the test has been extremely severe. The trees are of the most susceptible age as they are just coming into bearing and growing thriftily, and the chances for infection are unusually good, as the early plantings in the vicinity embraced two very susceptible varieties which served to carry blight over winter.

Under these conditions the following varieties have proved quite susceptible to blight: Alexander, Bismarck, Fallawater, Jonathan, Opalescent, Palouse, Sierra Beauty, Newtown Spitzenburg, Wagener, Wealthy, and Winter Banana. Of this list Jonathan, Wagener, and Wealthy are popular and possibly they may be safely grown later, as the severity of the blight attack may, and probably will, lessen with the destruction of the most susceptible varieties, especially the crab apples and the Alexander. Jonathan, however, does not make good size unless on very good soil and then the fruit is often immature. Wagener does well on good soil and matures well. It is not a good grower on light soils and in the majority of cases would do better if top-worked or grafted on a stronger root system. Aside from its susceptibility to blight, Wealthy is one of the most promising commercial varieties of the valley or in fact of Montana. In this variety blight has been particularly serious as it so often attacked the tree at the crown, just below the surface of the ground. If double-worked well above the ground or top-worked on resistant stocks, blight could no doubt be controlled in the top, but it would seem unwise to plant common budded or grafted trees where the Wealthy body extends below the surface of the ground. In addition to susceptibility to blight, Bismarck scalds badly in storage and Sierra Beauty and Newtown Spitzenburg do not mature well. The others have proved so susceptible to blight it would seem unwise to plant them.

Other varieties of this list maturing too late to develop good size, color, and quality are Akin, Lawver, Yellow Newtown, and possibly King David, Arkansas, and Stayman Winesap. On good, fertile soil of a character that would dry out well in the latter part of the season, these last two varieties may mature well enough to be of commercial value. While these two keep well into the spring in good, moist storage, the Arkansas is inclined to scald and both to shrivel if the storage cellar is not kept moist. Orenco, Winterstein, and Wismer Desert mature well but their storage season is short and they really have little to recommend them for commercial planting. The last two are desirable varieties for the home orchard and in common storage Wismer Desert will last until Thanksgiving and Winterstein until about Christmas. British Columbia has proved too tender to winter temperatures and trees planted for Marshall and Vandevere proved to be other varieties.

Of the remaining varieties, Coos River Beauty and Northern Spy need further testing although both appear promising.

Ontario matures well and makes good size. It is rather tart for dessert purposes and shows bruises quite badly if roughly handled, but it is excellent for cooking and keeps well in good cellar storage until the first of March or later. It is not particularly attractive at picking time but comes out of storage with a very attractive yellow background, partially and sometimes almost wholly covered with an attractive red blush.

Rome (Beauty) is fairly satisfactory as a commercial variety but on the majority of soils would profit by being top-worked upon a stronger root system.

Vanderpool Red has given promise of being one of the best late-keeping apples tested. It matures well, has attractive shape and almost solid red color, stands handling well, would be considered of better quality than Rome, and keeps exceptionally well. In good cellar storage a large percentage of the fruits will keep in excellent condition until May 1st or even later. The variety has also withstood blight very well and has borne unusually well for young trees. It is a variety that would apparently thrive on good soil, soil even above the average in fertility, and would probably require more or less thinning with age.

McIntosh has done well in our tests and is well known as the

most important commercial variety of Montana. Delicious trees planted in 1909 have not fruited abundantly as yet but the variety gives promise of being worthy of planting under such conditions of soil and exposure as favor good growth and early maturity. As yet we cannot recommend it for extensive commercial planting. The trees planted in 1909 as Yellowstone Pippin proved to be Ben Davis and this variety is undesirable for commercial planting in western Montana.

Of the other varieties planted in 1909 little can be said as the number of trees planted does not constitute a fair test.

Gravenstein trees planted in 1911 bore some fruit the past season. The variety seems to have some merit for commercial planting. The young trees are not as hardy as many other varieties but with age become more resistant to low winter temperatures.

APRICOTS

The plantings of 1908 and 1909 included the following varieties of apricots, in most cases a single tree of each variety:

Alexander	Harris	Tilton
Blenheim	Montgamet	Stella
Colorado	Moorpark	Superb
Early May	Royal	

We must admit this does not constitute a fair test, yet the general results with apricots indicate that they have little commercial possibility in this section of Montana. Superb, Moorpark, Harris, and Alexander have borne occasional crops of fruit. The wood as well as the fruit-buds of all varieties suffers more or less winter-injury and on account of early blooming the crop is subject to late spring frost injury. With proper site, soil, and care this fruit is worthy of trial in the home orchard. The orchard site should slope to the north or northeast, the soil should be of such a character that it will dry out and allow the trees to mature early in the fall, and care must be taken not to force too heavy growth by late irrigation or late cultivation.

CHERRIES

In 1908 ten trees each of the following varieties of cherries were planted:

Sweet	Sour
Bing	Baldwin
Centennial	Dyehouse
Lambert	Ostheimer
Napoleon (Royal Ann)	Vladimir
	Wragg

In 1909 one tree each of the following varieties of sour cherries was set out:

English Morello	Montmorency Sweet
Montmorency King	Montreuil
Montmorency Large	Suda Hardy
Montmorency Monarch	Terry
Montmorency Stark	Timme

No attempt has been made to replace trees lost in single-tree lots but in other cases replants have been made to maintain blocks of ten trees of each variety. With the exception of Montreuil and Suda Hardy, all the varieties have fruited. In general the sour varieties have been very satisfactory. The plantings of 1908 produced a crop of fruit in 1911 and have not missed a crop since. The trees have passed the winters well; during only one winter has there been any appreciable injury to fruit buds and then not serious enough to reduce the crop materially. Of the varieties tested, Dyehouse is the most promising early sour cherry and English Morello and Wragg are the most promising late ones. Baldwin as an early cherry has also yielded some good crops but seems more susceptible to winter-injury to the fruit buds than the other three mentioned. Ostheimer and Vladimir have fruited well, but the fruit is small. The single tree of Terry has performed well and the variety is worthy of further testing.

In general the sweet cherries have not been very satisfactory on our particular site. The trees have suffered more or less winter injury to the wood as well as the fruit buds. The site of the station orchard is not the best in the valley from the standpoint of late spring frosts, neither is it the worst. The crop has on several occasions been seriously injured by late spring frost. Of the varieties tested, Centennial seems to stand the winters best but the fruit cracks badly at ripening time and the variety would not be considered

a good commercial cherry. In yield, Bing stands next to Centennial, with Lambert third and Napoleon last.

It is possible that in our tests poor results with the sweet cherries may be attributed in part to soil conditions. The cherry plots have received clean cultivation for the most part and chemical analyses made in the summer of 1916 showed the soil very deficient in nitrogen. It is not improbable that some of the injury to the trees which has been entered in the notes as winter-injury might be more properly referred to as a "die-back" resulting from lack of plant food, particularly nitrogen. But if the sweet cherry is to succeed commercially, it is safe to say that it must have favorable soil and a site well protected from late spring frosts.

PEARS

Varieties of pears have been planted as follows:

In 1908 ten trees each of

Bartlett	Flemish (Beauty)
Clapp (Favorite)	Seckel

In 1909 single trees of

Alamo	Fame	Riehl's Best
Clarksville	Jones Winter	Rossney
Comice	King Karl	Snyder
Easter (Buerre)	Lincoln	Triumph
	Ozark	

In 1911 ten trees of Mount Vernon.

In 1914 five trees each of Anjou, Winter Nelis, and Comice.

In 1915 five trees each of Lincoln and Fame.

The trees planted in 1908 and 1909 have passed through a severe blight test and most of them have been destroyed. Of those planted in 1908, Bartlett and Seckel were most resistant; and of those planted in 1909, Fame and Lincoln withstood the blight best. The Mount Vernon trees planted in 1911 have borne one crop of fruit which was very promising from the standpoint of size and quality. So far only one tree has been lost by blight. In other sections this variety has been noticeably resistant to blight and it is hoped that it may prove so in Montana. In any locality one of the greatest difficulties in growing pears is blight. In our case, the test has been severe on account of the heavy nearby plantings of susceptible varieties of apples which carried the blight over winter and provided for heavy blossom infections in the spring. With most of these

varieties now out of the way, pear-growing should not be such a hazardous venture.

Of the varieties tested, Bartlett is the most promising for a commercial pear. Mount Vernon, Fame, and Lincoln are also promising but need further testing before they are planted extensively.

PEACHES

The following varieties of peaches were planted in 1908 and 1909:

Alton	Elberta Queen	Ozark
Arp Beauty	Engle Mammoth	Poole Favorite
Belle Georgia	Fitzgerald	Pres. Lyon
Capt. Ede	Gov. Hogg	Ray
Carpenter	Greensboro	Red Bird Cling
Champion	Hiley	Russel
Crawford	Hyslop	Sea Eagle
Early Elberta	Illinois	Uneeda
Early Mamie Ross	Crummel October	Washington
Edgemont	Mayflower	Woosley
Elberta Cling	May Lee Cling	Worth

In most cases only a single tree of each variety was set. In some instances the trees did not survive the first growing season and in many more cases the first winter. No attempt was made to replace lost trees as it did not seem worth while to test single trees, and space and funds were not available for more extensive testing. Trees of three or four varieties have survived the winters and the variety Illinois has borne several crops of fruit. While there is little hope that peaches will succeed commercially in the valley, there are no doubt varieties that could be quite successfully grown in the home orchard. In 1916 five trees each of the varieties, Champion, Eureka, Red Bird Cling, and Triumph were planted. This we hope will be the beginning of a more systematic test of peach varieties.

PLUMS

Plums have not been extensively tested and in the majority of cases the number of trees planted has been too small to give a fair test. Trees of the following varieties were planted in 1908 and 1909:

America	Hammer	Omaha
Combination	Hungarian Prune	Poole Pride
Daisy	Late Goose	Purple Flesh
Diamond (Black)	Mathews	Red June
Earliest of All	Maynard	Stella
Freestone Goose	Missouri Green Gage	Victor
Gold	Muncy	Wickson

In 1915 five trees each of the varieties, Abundance, America, Lombard, Purple Flesh, and Tatge were planted.

The varieties Hungarian Prune, Maynard, Omaha, Red June, and Wickson have, we believe, been given a fair test both in number of trees and in time. Omaha is really the only promising variety. The Hungarian Prune trees grow very well but the crops have been light in most seasons on account of winter-injury or late spring frost injury to the fruit buds. In years when the variety produced a good crop the season has hardly been long enough to mature the fruit well. Maynard, Red June, and Wickson will not withstand the winter climate. The other plantings of 1908 and 1909 were in most cases single trees of a variety. It seemed hardly worth while to continue the test on so small a scale and space and funds were not available for more extensive plantings of plums, so in case trees were lost replants were not made. The plums no doubt have some commercial possibilities in the valley and the plantings of 1915 were the beginning of a more systematic test. Little information is available as to the adaptability of varieties although plums are more or less grown throughout the valley.

WALNUTS

The plantings of 1908 included some varieties of walnuts of the class commonly known as English walnuts. Ten trees each of the varieties Mayette, Franquette and Sieboldi have been tested. We have not been able to grow any of these trees to any size, the wood killing back each winter and in severe winters trees being killed outright.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION
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Investigations of Irrigation Pumping Plants

BY
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PREFACE

The experiment reported in this bulletin was planned and the laboratory tests carried on by H. B. Bonebright, formerly assistant agricultural engineer of the Experiment Station. Mr. Bonebright resigned before the material was made ready for publication. Later tests were made by H. E. Murdock, at present agricultural engineer of the Experiment Station, who prepared all the data for publication.

The tests herein described were made possible by the cooperation of various companies who lent equipment and of farmers whose plants were tested. We are indebted to the following companies for machinery lent: American Well Works, Aurora, Ill., 7-inch vertical centrifugal pump; Byron-Jackson Iron Works, San Francisco, Cal., 5-inch vertical centrifugal pump; J. I. Case Threshing Machine Company, Racine, Wis., tank pump and fittings, 75-horse-power steam traction engine, and 36-horse-power steam road roller; "Friend" Manufacturing Company, Gasport, N. Y., 4-horse-power spray motor; Fuller & Johnson Manufacturing Company, Madison, Wis., ¾-horse-power gasoline engine and pump jack; Goulds Manufacturing Company, Seneca Falls, N. Y., 3-inch horizontal centrifugal pump, and Pyramid plunger pump; International Harvester Company of America, Chicago, Ill., 45-horse-power gasoline-kerosene tractor, 5-horse-power gasoline engine, and 1-horse-power gasoline-kerosene engine.

The pumping plant owners whose plants were tested and who showed many courtesies and gave valuable assistance in testing their plants were M. L. Wilson of Fallon; B. F. Shreve and Olof Person of Decker; the Hysham Ditch Company of Hysham; Peter Hardenberg of East Scobey; L. L. Crockett of Forsyth; the Montana Reservoir and Irrigation Company of Helena; and the Lockwood Irrigation Company of Billings.

F. B. LINFIELD, Director.

Investigations of Irrigation Pumping Plants

Public lands in the United States adapted to cultivation are rapidly diminishing. Practically all of the arid land that can be reclaimed at a small expenditure by the gravity irrigation method is privately owned. There are places where land could be irrigated by pumping from wells or streams but whether it would pay to go to the expense of installing a plant and pumping water for the reclamation of such lands is a question that one needs a large amount of information to answer. At many places in the United States irrigation pumping plants have been installed and have proved to be failures, while many other plants have been successful. The failures have been due mostly to poor installation, inefficient handling of the plant, and lack of proper water, soil, irrigation, crop, and marketing conditions.

When good water is available in sufficient quantities, irrigation by the use of an individual pumping plant has certain advantages over gravity irrigation. The owner is not dependent upon other people for the delivery of his water supply, he can irrigate when he chooses to do so, he usually has free use of the water without interference from outside parties, and he is not dependent upon any irrigation canal but his own. He is therefore the gainer if he succeeds and the loser if he fails. On the other hand the gravity system of irrigation has certain advantages over pumping. Aside from the relative merits of the two systems of irrigation, there are lands for which a supply of water can be obtained only by pumping and there is no choice between methods. The question then to be decided is whether pumping will be justified by the returns to be obtained.

NATURE OF THE INVESTIGATIONS

Many tests and investigations have been made of pumps and pumping plants used for irrigation, but few, if any, have been made to bring out the results of using various combinations of motive power and pumps that may be found on farms and used for other

purposes than irrigation. A great many tractors have been bought by farmers in Montana, and these furnish a power that might be used for irrigation pumping. Orchardists may own power sprayers and the question is raised whether they could be used economically for pumping irrigation water. There are many small engines on the farms which may be used for power to pump water. There are various kinds of fuel available in the State for developing power. If such motive power as is found on the farms can be used economically for irrigation pumping, the farmer should be able to find out the pump best suited for combining with his power and lift. If his conditions will not warrant the installation of a pumping plant, figures should be available to show the reason.

For the investigations herein described twenty-nine laboratory and three field tests were made during the seasons of 1912 and 1913. These consisted of various combinations of engines and pumps for different heads. To supplement these tests and secure information on pumping plants as installed in the State, sixty-three tests of such plants and four laboratory tests were made during the season of 1915. A number of the latter tests were made on electrically driven pumps and these are not reported in this bulletin.

TERMS AND ABBREVIATIONS USED

Throughout this publication certain units and abbreviations are used and some of them are listed below:

r. p. m. is number of revolutions per minute.

h. p. is horse-power, which is the rate of doing work.

Lift is the total vertical distance through which the water is pumped.

Acre-foot is a volume of 43,560 cubic feet, which is sufficient to cover one acre to a depth of one foot. **Acre-inch** is one-twelfth of an acre-foot.

Foot acre-foot is the amount of work done in raising a volume of one acre-foot a vertical distance of one foot. In this bulletin it refers to water.

Pressure head is the length of a vertical column of water, without motion, that would give the pressure in the discharge pipe just above the pump. This is recorded on the pressure gage placed on the discharge pipe.

Vacuum head is similar to pressure head in that it represents a vertical length of water, but it is the number of feet suction just below the pump in the suction pipe. This is represented by the reading on the vacuum gage placed on the suction pipe.

Velocity head is the vertical distance through which a freely falling body would have to drop to attain the given velocity.

Head on pump is the sum of the pressure head, the vacuum head, and the difference in the velocity heads below and above the pump bowl.

Water horse-power or the useful horse-power represents the rate of doing the work of lifting the water through the vertical distance pumped.

Brake horse-power is the amount of power absorbed by the Prony brake when attached to the fly-wheel of the engine or to the shaft of the pump.

METHOD OF COLLECTING DATA

Several kinds of pumps and engines were tested in the laboratory located at the Experiment Station. The pumps, engines, belts, and so forth, were such as may be found on farms, and they were tested under conditions approaching actual field conditions as nearly as possible. The lifts were 10 feet, 25 feet, and 50 feet.

Near a small stream on the college farm a concrete sump 10 feet in diameter and 6½ feet deep was built. Above this was built a tripod of strong poles 50 feet high. At the side of the sump and slightly above it was located a weir box. The pumps were installed in or above the sump and the discharge pipes were located in the tower. At the desired heights, long sweep elbows turned the water into a large wooden pipe which conducted it down into the weir box. As the elbows directed the water through large openings in the side of the wooden pipe, no siphoning was possible. The large wooden pipe conducted the water to the end of the weir box farthest from the sump. The water passed through a perforated partition which effectually removed bubbles and eddies. It then moved slowly to the Cippoletti weir, over which it flowed into another compartment of the weir box. It then flowed into the sump to be pumped again to the top of the discharge pipe. A uniform depth was maintained at all times in the sump. Any water wasted was replaced by a small auxiliary pumping plant which delivered water from the nearby

FIG. 1. General view, showing site of laboratory tests and station buildings in background.

FIG. 2. Testing a pump. Weir and sump also shown.

stream to the sump. Figure 1 is a view taken at the site of the laboratory experiments at the time of the tests. Figure 2 is a near view of an outfit being tested and it also shows the sump and weir box.

In the field tests made in 1915, as the speed of engines and pumps is seldom constant, readings were made periodically, usually at intervals of 15 or 30 minutes. All gages as well as speeds were also read, and the results given in this bulletin are the averages of all readings taken on the various items enumerated. To make the information as complete as possible, a description of the plants, including costs, crops and acreages irrigated, systems of operating plants, rate of irrigating, cost of help, days used in a season, and so forth, was obtained, as well as engine speed, pump speed, vacuum below pump, pressure above pump, lift, rate of discharge, fuel consumption, and lubricating oil consumption.

As the feasibility of pumping for irrigation depends upon its cost and the additional returns due to irrigation, a few data on the returns were obtained, but there is not enough information available for drawing definite conclusions. In making an estimate for a proposed installation, the best that can be done is to guess at the benefits to be derived or try to make estimates from comparisons of irrigated and non-irrigated crops in the neighborhood of the proposed plant.

APPARATUS USED IN TESTS

PUMPS

The pumps tested in the laboratory were as follows:

J. I. Case thresher tank plunger pump with a diameter of 5 inches and a stroke of 5⅛ inches.

FIG. 3. Byron-Jackson vertical centrifugal pump.

MEASUREMENT OF THE LIFT

The lift, as measured in the laboratory tests, was the distance from the surface of the water in the sump to the bottom of the discharge elbow, while in the field tests it was measured to the center of the issuing stream or to the surface of the water in the discharge flume where the end of the discharge pipe was submerged.

The suction lift for the horizontal reciprocating pumps was considered as the vertical distance from the water surface to the center of the piston, and for the horizontal centrifugal pumps the distance to the center of the shaft. The lift above pump for the horizontal reciprocating pumps was measured from the center of the piston, for the horizontal centrifugal pumps from the center of the shaft, and for the submerged centrifugal pumps from the surface of the water in the sump.

TESTS FOR POWER CONSUMPTION

The power required to pump the water and to overcome friction was determined at the laboratory as follows: At the end of the full day tests the speeds at which each pump must be run to raise the desired amount of water to the different heights were known. A large steam engine was then belted to the pump and the belt passed through the dynamometer as shown in figure 5. By means of this dynamometer it was possible to weigh the pressure at x caused by the upper belt being tighter than the lower belt. A run of several minutes was made at each height, namely, 10 feet, 25 feet, and 50 feet. The speed of the pump was maintained the same

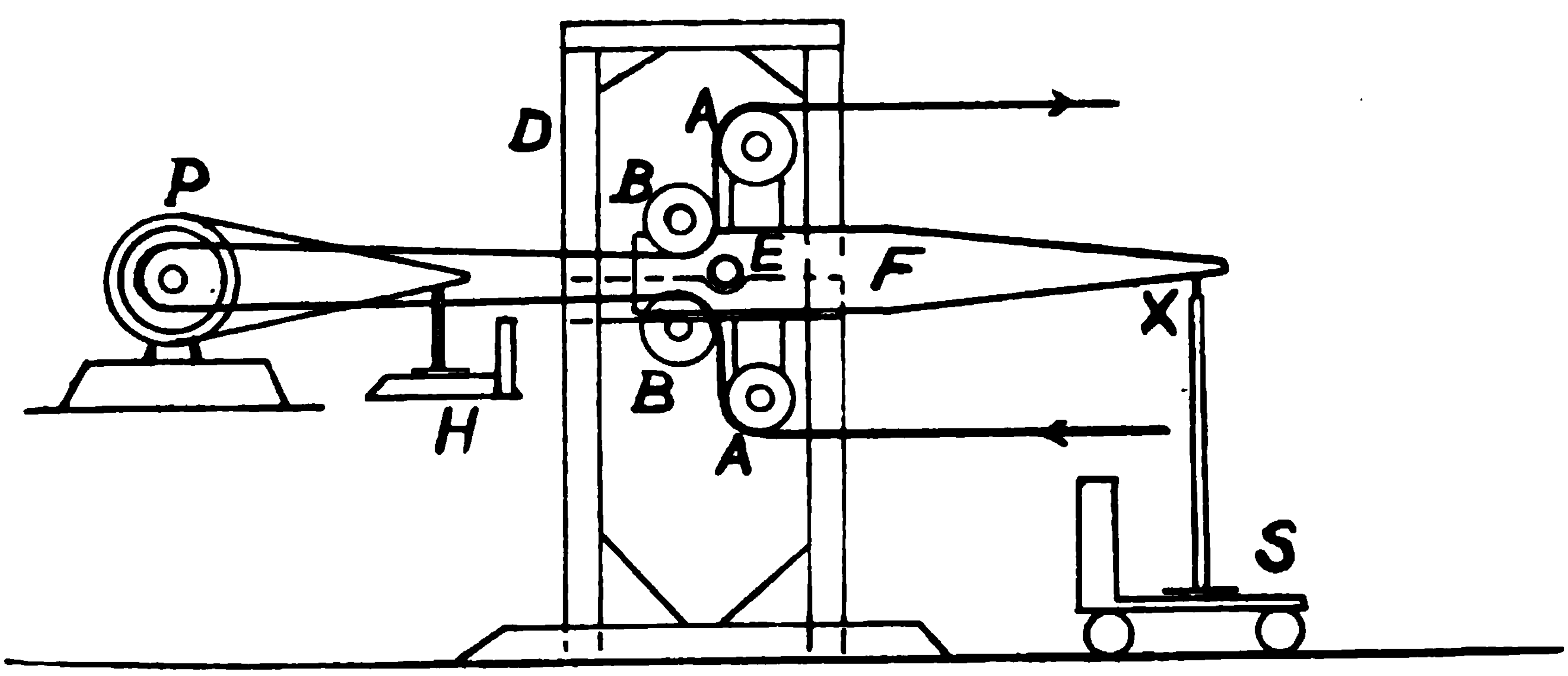

FIG. 5. Arrangement of transmission dynamometer.

as for the pumping tests and the force at x was determined for each height of lift. The runner and shaft of the pump were then disconnected and a Prony brake was applied on an extra wheel, so arranged as to take the place of runner or impeller, stuffing box, and neck bearing of the pump. The engine was again run to give the same shaft speed as the pump had when throwing the required quantities of water to each of the three different heights. The Prony brake was adjusted until the force at x corresponded to that exerted when running the pump. The force exerted on the arm of the Prony brake, the length of the brake arm, and the revolutions per minute were noted, and from these data the horse-power was computed. These tests do not include the power necessary to drive the shaft bearings outside of the pump, or that used in driving the belt.

The following precautions were observed: (1)The tension on the belt was kept the same for the dynamometer tests as for the pump tests. (2) All bearings were kept well oiled during both pump and dynamometer tests. (3) The same fittings and arrangements of bearings and shafting were used as in the 10-hour pumping tests.

FIG. 6. Prony brake.

In the brake test made in the field the belt was removed from the driving pulley and a rope brake was attached to one of the fly-wheels. The moment necessary to reduce the speed of the engine to that maintained while pumping was determined and the power was calculated from this. This method probably would not be applicable in many cases, but it is believed to be sufficiently accurate for the purpose of this test. Figure 6 shows the brake as attached to the engine.

MEASUREMENT OF FUEL AND FEED WATER

In the laboratory tests, after the engine and pump had been operated for a short time as a test of the installation, the engine was stopped and all fuel was drained from the tank. Then gasoline or kerosene was weighed into the tank and the plant was run. At the end of the run the fuel which remained in the tank was drawn out and weighed. The net fuel used by the engine was thus determined. In the field tests the tanks were filled at the start of the test and refilled at the end of the run, the amount being weighed to determine the amount of fuel used. The specific gravity of the fuel was also determined.

For the steam engine laboratory tests the engine was fired until the steam pressure was up to the average for the run. The plant was started and when it was running smoothly with an even fire, the height of the water in the gage glass was marked and the service water meter was then connected to the injector intake hose. At the end of the run the water in the boiler was brought to the same height as at the start, and the fire was brought to as nearly average conditions as possible. The overflow from the injector during the 10-hour run was weighed, and this amount taken from the total weight indicated by the service meter gave the amount of water used. The amount of coal or lignite used was determined by weight, but it does not include that used in the "firing-up" process. The weights given simply represent the amounts of fuel used in the ten hours of actual running time in pumping the water. It was impossible to run the full ten hours in some of the laboratory tests, but in these the fuel and water have been computed on a 10-hour basis for comparison. Notes on running conditions were kept in each test made.

In the field tests of steam plants the amount of water fed to the boiler was not determined. A mark was placed on the gage glass and the water kept near that point all the time. Accidental popping of the safety valve was avoided. Aside from this the usual operating conditions were maintained during the tests. The coal used was weighed. In computing the fuel costs for the field tests the prices paid for the fuel were used. As the prices and lifts vary so much, all the tests, both laboratory and field, have been reduced to a common basis, which is the amount necessary to raise one acre-foot a vertical distance of one foot.

CALCULATIONS

The calculations have been made by the aid of the slide rule as the field measurements would not justify carrying the computations to more than three or four places, and that is a degree of exactness as great, if not greater, than the accuracy of most of the published weir tables.

To reduce all tests to a common basis for comparison and discussion, the fuel consumption necessary to lift one acre-foot of water a vertical distance of one foot was obtained and tabulated in the columns headed "Fuel per foot acre-foot" in Tables I and II. In all cases the values for this column were obtained by taking the total vertical distance of the discharge above the surface of the water in the supply bay for the lift. This gives the consumption for the useful lift and not for the total head on the pump, which can be obtained by attaching gages to the intake and discharge pipes. The total head on the pump was not obtained in the tests made in 1912 and 1913 and in one of the tests made in 1915, so the values as given include friction in intake and discharge pipes.

By reducing the fuel consumption to the amount per foot acre-foot we eliminate the factor of the varying cost of fuel in different parts of the country, and the results can be applied in making estimates anywhere.

SUMMARY OF RESULTS

On account of the bulk of the data it was decided not to publish the details of the tests but anyone especially desirous of securing them can obtain copies on request.

TABLE I. SUMMARY OF RESULTS OF LABORATORY TESTS.

Test number	Engine: Rated horse-power	Engine speed (r. p. m.)	Pump speed (r. p. m.)	Discharge of pump (cu. ft. per sec.)	Kind of pump	Lift (feet)	Fuel per acre-foot (gals. or lbs.)	Fuel per foot acre-foot (gals. or lbs.)	Lubricating oil per foot acre-foot (gals.)
				GASOLINE ENGINES					
*1	¾	....	....	0.054	Plunger	10	9.4	0.94	0.224
*1a	¾	....	....	.054	do.	25	14.32	.573	.224
†2	4	....	....	.0191	do.	50	156.	3.12	.253
‡3	4	....	....	.0679	do.	50	52.4	1.05	.071
‡64	1	....	....	.055	do.	8.2	....	3.48	....
‡65	1	....	....	.057	do.	8.2	....	3.74	....
‡66	1	....	....	.058	do.	8.2	....	2.51	....
4	4	385	342	.3447	Cent'l 3-in. horiz.	10	9.38	.938	.070
5	4	600	393	.6	do.	10	8.48	.848	.040
6	5	284	392	.6	do.	10	7.04	.704	.040
7	5	318	548	.6	do.	25	16.85	.674	.016
8	45	274	548	.6	do.	25	38.2	1.528	.064
11	45	272	1055	.6	do.	50	45.8	.916	.064
13	5	424	676	1.276	Cent'l 5-in. vert.....	10	11.8	1.18	.019
14	5	366	726	1.5	do.	10	7.03	.703	.016
16	45	315	876	1.5	do.	25	24.36	.974	.026
18	45	325	1135	1.5	do.	50	30.2	.604	.013
21	45	314	336	3.	Cent'l 7-in. vert.....	10	12.2	1.22	.027
22	45	300	462	3.	do.	25	15.6	.623	.011
25	45	306	602	3.	do.	50	21.3	.424	.011
				KEROSENE ENGINES					
67	1	....	....	.06	Plunger	8.2	....	2.72	....
12	45	272	1055	.6	Cent'l 3-in. horiz.	50	52.6	1.052	.04
§15	5	366	726	1.5	Cent'l 5-in. vert.....	10			
17	45	315	876	1.5	do.	25	23.6	.944	.026
19	45	325	1135	1.5	do.	50	29.5	.59	.013
23	45	300	462	3.	Cent'l 7-in. vert.....	25	15.6	.625	.011
26	45	306	602	3.	do.	50	20.8	.416	.011
				STEAM ENGINES USING COAL					
9	36	214	548	.6	Cent'l 3-in. horiz.	25	1750.	70.	.024
10	36	255	1055	.6	do.	50	3270.	65.4	.024
20	75	228	1135	1.5	Cent'l 5-in. vert.....	50	1423.	28.5	.01
24	75	212	462	3.	Cent'l 7-in. vert.....	25	708.	28.3	.008
27	75	212	602	3.	do.	50	1010.	20.2	.008

*Thresher tank pump. †Spray pump. ‡Double-acting pump. §Engine would not operate successfully on kerosene.

TABLE II. HORIZONTAL CENTRIFUGAL PUMPS. SUMMARY OF RESULTS OF FIELD TESTS

Test number	Engine: Rated horse-power	Engine speed (r. p. m.)	Diameter of discharge pipe (in.)	Pump speed (r. p. m.)	Discharge of pump (cu. ft. per sec.)	Lift (feet)	Kind of fuel	Fuel cost per unit (dollars)	Fuel per acre-foot (gals. or lbs.)	Fuel per foot acre-foot (gals. or lbs.)	Lubricating oil per foot acre-foot (gals.)
							STEAM ENGINE PLANTS				
28a	75	170	6	370	2.33	12.65	Lignite	3.00	1304	103	0.0246
29a	75	236	6	532	3.06	37.6	do.	3.00	1467	40.1	.0187
30a	75	236	6	532	3.06	37.6	Coal	5.00	1128	30.	.0187
7	65	205	18	257	15.12	14.23	do.	4.00	538	37.8	.00433
8	65	220	18	276	19.73	14.45	do.	4.00	471	32.6	.00258
*9	65	...	18				do.				
10	65	219	18	275	20.23	14.5	do.	4.00	380	26.2	.00172
†11	65	...	18				do.				
8–11	65	...	18	‡		14.47	do.	4.00	432	30.0	.00215
§12	65	...	18				do.				
13	65	237	18	298	25.	14.77	do.	4.00	450	30.5	.002
¶14	65		18								
							GASOLINE ENGINE PLANTS				
1	12	130	6	251	1.6	4.6	Gasoline	0.16	6.37	1.38	....
2	12	135	6	264	1.45	4.35	do.	.16	6.70	1.54	.09
‖3	12						do.				
4	12	128	6	248	1.61	4.5	do.	.16	6.34	1.41	....
5	12	127	6	247	1.65	4.42	do.	.16	6.40	1.45	....
6	15	230	6	373	2.72	12.	do.	.16	9.	.75	....
16	8	289	8	274	.97	11.5	do.	.19	8.36	.755	.049
17	8	291	8	278	1.17	11.5	do.	.19	6.20	.54	.034
							KEROSENE ENGINE PLANT				
56	20	233	10	280	5.56	10.	Kerosene ...	.11	5.73	.573	.009

*Test to determine cost of stopping plant to clean boiler and eat lunch. †Test run to reduce steam in boiler before stopping. ‡Normal. §Test run to determine cost of starting up after closing down for night. ¶Test run to reduce steam. ‖Brake test run to determine power of engine and power used in pumping.

Table I gives the results of the laboratory tests and Table II gives those of the field tests. In these tables the amount of fuel and lubricating oil used is reduced to a uniform basis for all plants and all lifts, and that is the amount used in lifting one acre-foot of water one foot.

The three centrifugal pumps used in the laboratory experiments were tested for efficiency according to the method described on page 134 with the results given in Table III. "Brake horse-power" in the table indicates the power obtained on the brake which was

TABLE III. BRAKE AND WATER HORSE-POWER AND EFFICIENCY OF CENTRIFUGAL PUMPS TESTED AT THE LABORATORY

Pump	Head on pump (feet)	Discharge (cu. ft. per sec.)	Brake horse-power	Water horse-power	Efficiency (per cent)
Gould 3-inch horizontal centrifugal pump	10	0.6	1.859	0.68	36.6
	25	0.6	3.58	1.70	47.5
	50	0.6	6.70	3.40	50.7
Byron Jackson 5-inch vertical pump (submerged)	10	1.5	3.456	1.70	49.2
	25	1.5	7.84	4.25	54.2
	50	1.5	14.48	8.50	58.7
American 7-inch vertical centrifugal pump (submerged)	10	3.0	7.80	3.40	43.6
	25	3.0	13.37	8.50	63.6
	50	3.0	23.84	17.00	71.3

attached to the pump shaft, and "water horse-power" indicates that represented in lifting the water pumped.

The table shows that it took from about 40 per cent to 174 per cent more power to run these pumps and lift the water than to lift the water alone. When we consider, too, that the horse-power requirements as shown are for running the impeller, stuffing boxes, and neck bearings of pump only, and do not include the friction losses in outside bearings, belts, etc., it is apparent that the power developed by the engine was greater than that delivered to the dynamometer. It is impossible to state exactly how much greater as different systems of belting to the shaft and different methods of hanging the shafts will influence the amount of power necessary for the driving of the pump. This table indicates that the pumps developed the highest efficiency for the greatest lifts. For the lower lifts other rates of discharge would give other efficiencies, and the highest efficiencies of the pumps may be developed at some other rates of discharge and at some other lifts than these given.

FUEL

CONSUMPTION

There are many factors which influence the rate of fuel consumption in gasoline engines. With everything adjusted properly for the engine to develop high efficiency, changing the setting of

the needle valve will cause a big difference in the fuel consumption. According to experiments the same engine in good working condition may consume more than 50 per cent more gasoline than necessary for the maximum load and more than 200 per cent more for half load without any indication by the engine that an excess of fuel is being used.

Other factors affecting the fuel consumption of an engine are time of ignition, speed of engine, size of engine, carburation, throttling, valve timing, jacket temperature, intensity of ignition spark, degree of compression, and the mechanical condition of the engine, such as the original design, leaks from wear, and so forth.

Aside from these factors the tests herein described throw considerable light upon the subject of the practice of irrigation by pumping, and the results of these tests agree with the results of more than one hundred tests made on pumping plants in the Great Plains area and in the artesian district in southern Nevada.

Any conclusions that may be drawn are only tentative and are subject to modification, as not a sufficient number of tests has been made under various conditions to be able to deduce laws.

From the observations made it may be concluded that a plant should be capable of raising one acre-foot of water one foot on a half gallon of liquid fuel. This means the lifting of more than six hundred and fifty thousand times its volume of water one foot and represents an over-all efficiency of about 20 per cent. This includes the friction in the suction and discharge pipes for the ordinary installation where the pipes are not very long or where they are sufficiently large. Although not so many tests of steam plants have been made, the data indicate that this amount of work should be done on twenty to thirty pounds of coal. It has been found from the results of the tests of electrical plants that this amount of work should be done on about two kilowatt hours. If pumping plants as installed do not give as good efficiency as stated, they should be investigated for the trouble, since under existing conditions of design such efficiencies are being obtained.

COST

There is nothing in the data which would indicate that the amount of fuel per foot acre-foot depends upon the lift. The cost

of this item per acre-foot may be assumed for the present as being directly proportional to the lift.

The fuel cost is easily obtained for any actual installation and it is not a difficult matter to make an estimate for a proposed installation. From the conclusions just given a plant operating under favorable conditions should not require more than a half gallon of liquid fuel per foot acre-foot, or twenty to thirty pounds of coal, or two kilowatt hours of electrical energy. When the total lift and the price of fuel or power are known, the fuel cost can be estimated. For example, assume a 20-foot lift and the price of gasoline 25 cents a gallon and coal $5 a ton. One acre-foot of water would require about 10 gallons of gasoline, costing $2.50, or about one-fourth ton of coal, costing $1.25.

LUBRICATING OIL

CONSUMPTION

The amount of lubricating oil required per foot acre-foot for the machinery is ordinarily a relatively small item and varies between wide limits. It depends upon the operator of the plant as well as the machinery. The amount needed may be estimated between 0.01 and 0.04 gallon, depending upon the conditions. It is noticed in the data of the laboratory tests that the amount of lubricating oil used in a 10-hour run for a given outfit was the same for all loads on the outfit. This may be the case in practice, especially since the oil consumption is relatively small.

COST

The cost of lubricating oil is comparatively small but in the course of a season it amounts to a good figure and should be included in estimates. As just stated, the amount of lubricating oil used per foot acre-foot may be estimated between 0.01 and 0.04 gallon. Assuming a 20-foot lift and the price of lubricating oil to be 50 cents a gallon, the cost per acre-foot of water would be about 25 cents.

OTHER COSTS OF OPERATING PUMPING PLANTS

In the operation of an irrigating pumping plant there are several items of the total cost that can be more or less separated. In addition to fuel and lubricating oil cost there are interest and depreciation, engineer, and irrigator. In some cases there may be a charge for

water right or water. All these items need to be carefully considered by the person expecting to install a plant as they may represent the greater part of the operating expenses. These items will vary between wide limits for the different pumping plant installations as found in the pumping districts. Some of the factors affecting the costs for these items are size of plant, life of plant, rate of pumping, length of pumping season, fuel used, lift, type of machiery, and so forth.

COMPARISONS

There are some instructive comparisons that may be made from the data as given which will indicate the wide variations that may be had. Before drawing final conclusions as to the merits of the engines, their condition, management, and adjustment should be considered. In order to make comparisons readily Tables IV and V have been arranged. These contain the summary of the results of the laboratory tests, all the tests on each pump being grouped in Table IV and all the tests for each lift in Table V.

As an example of the comparisons that may be made, take the gasoline used by the 45-horse-power tractor when driving the 7-inch pump at the various lifts. It is noted that for the 10-foot lift the amount required per foot acre-foot was 1.22 gallons; for the 25-foot lift, 0.623 gallon; and for the 50-foot lift, 0.424 gallon (see Table IV). This indicates that the combination gave the best over-all efficiency for the highest lift, which is probably due to the fact that the engine was developing more nearly its economical power at the highest lift and the pump was working with a high efficiency. The efficiency of the pump at the given rate of discharge and for the 50-foot lift as shown in Table IV is the highest for these conditions. For the lower lifts larger pumps should be used in combination with this tractor in order to reduce the fuel consumption per foot acre-foot. No such pumps were tested in these experiments.

By comparing laboratory tests No. 5 and 6 on the same pump and at the same lift, it is seen that one engine made a saving of 0.144 gallon of gasoline per foot acre-foot over the other engine (see Table V). For the 25-foot lift, test No. 7 shows a saving over test No. 8 of 0.854 gallon per foot acre-foot. This indicates the inadvisability of connecting the big tractor to a small pump for a small lift.

TABLE IV. SUMMARY OF RESULTS OF LABORATORY TESTS, GROUPED ACCORDING TO EACH PUMP

Test number	Engine: Rated horse-power	Engine speed (r. p. m.)	Pump speed (r. p. m.)	Discharge of pump (cu. ft. per sec.)	Lift (feet)	Kind of fuel	Fuel per acre-foot (gals. or lbs.)	Fuel per foot acre-foot (gals. or lbs.)	Lubricating oil per foot acre-foot (gals.)
				PLUNGER PUMPS					
*1	¾			0.054	10	Gasoline	9.4	0.94	0.224
*1a	¾			.054	25	do.	14.32	.573	.224
†2	4			.0191	50	do.	156.	3.12	.253
‡3	4			.0679	50	do.	52.4	1.05	.071
‡64	1			.055	8.2	do.	....	3.48	....
‡65	1			.057	8.2	do.	....	3.74	....
‡66	1			.058	8.2	do.	....	2.51	....
‡67	1			.060	8.2	Kerosene	....	2.72	....
				CENTRIFUGAL PUMPS					
				Three-inch horizontal pump					
4	4	385	342	.3447	10	Gasoline	9.38	.938	.070
5	4	600	393	.6	10	do.	8.48	.848	.040
6	5	284	392	.6	10	do.	7.04	.704	.040
7	5	318	548	.6	25	do.	16.85	.674	.016
8	45	274	548	.6	25	do.	38.2	1.528	.064
9	36	214	548	.6	25	Coal	1750.	70.	.024
10	36	255	1055	.6	50	do.	3270.	65.4	.024
11	45	272	1055	.6	50	Gasoline	45.8	.916	.064
12	45	272	1055	.6	50	Kerosene	52.6	1.052	.064
				Five-inch vertical pump					
13	5	424	676	1.276	10	Gasoline	11.8	1.15	.019
14	5	366	726	1.5	10	do.	7.03	.703	.016
§15	5	366	726	1.5	10	Kerosene			
16	45	315	876	1.5	25	Gasoline	24.36	.974	.026
17	45	315	876	1.5	25	Kerosene	23.6	.944	.026
18	45	325	1135	1.5	50	Gasoline	30.2	.604	.013
19	45	325	1135	1.5	50	Kerosene	29.5	.59	.013
20	75	228	1135	1.5	50	Coal	1423.	28.5	.01
				Seven-inch vertical pump					
21	45	314	336	3	10	Gasoline	12.2	1.22	.027
22	45	300	462	3	25	do.	15.6	.623	.011
23	45	300	462	3	25	Kerosene	15.6	.625	.011
24	75	212	462	3	25	Coal	708.	28.3	.008
25	45	306	602	3	50	Gasoline	21.3	.424	.011
26	45	306	602	3	50	Kerosene	20.8	.416	.011
27	75	212	602	3	50	Coal	1010.	20.2	.008

*Thresher tank pump. †Spray pump. ‡Double-acting pump. §Engine would not operate on kerosene.

TABLE V. SUMMARY OF RESULTS OF LABORATORY TESTS GROUPED ACCORDING TO LIFT

Test number	Engine: Rated horse-power	Engine speed (r. p. m.)	Pump speed (r. p. m.)	Discharge of pump (cu. ft. per sec.)	Kind of pump	Kind of fuel	Fuel per acre-foot (gals. or lbs.)	Fuel per foot acre-foot (gals. or lbs.)	Lubricating oil per foot acre-foot (gals.)
					8.2-FOOT LIFT				
*64	1			0.055	Plunger	Gasoline		3.48	....
*65	1			.067	do.	do.		3.74	....
*66	1			.058	do.	do.		2.51	....
*67	1			.060	do.	Kerosene		2.72	....
					10-FOOT LIFT				
†1	¾			.054	Plunger	Gasoline	9.4	.94	.224
4	4	385	342	.3447	Cent'l 3-in. horiz.	do.	9.38	.938	.070
5	4	600	393	.6	do.	do.	8.48	.848	.040
6	5	284	392	.6	do.	do.	7.04	.704	.040
13	5	424	676	1.276	Cent'l 5-in. vert.	do.	11.8	1.18	.019
14	5	366	726	1.5	do.	do.	7.03	.703	.016
‡15	5	366	726	1.5	do.	Kerosene			
21	45	314	336	3.	Cent'l 7-in. vert.	Gasoline	12.2	1.22	.027
					25-FOOT LIFT				
†1a	¾			.054	Plunger	Gasoline	14.32	.573	.224
7	5	318	548	.6	Cent'l 3-in. horiz.	do.	16.85	.674	.016
8	45	274	548	.6	do.	do.	38.2	1.528	.064
9	36	214	548	.6	do.	Coal	1750.	70.	.024
16	45	315	876	1.5	Cent'l 5-in. vert.	Gasoline	24.36	.974	.026
17	45	315	876	1.5	do.	Kerosene	23.6	.944	.026
22	45	300	462	3.	Cent'l 7-in. vert.	Gasoline	15.6	.623	.011
23	45	300	462	3.	do.	Kerosene	15.6	.625	.011
24	75	212	462	3.	do.	Coal	708.	28.3	.008
					50-FOOT LIFT				
§2	4			.0191	Plunger	Gasoline	156.	3.12	.253
*3	4			.0679	do.	do.	52.4	1.05	.071
10	36	255	1055	.6	Cent'l 3-in. horiz.	Coal	3270.	65.4	.024
11	45	272	1055	.6	do.	Gasoline	45.8	.916	.064
12	45	272	1055	.6	do.	Kerosene	52.6	1.052	.064
18	45	325	1135	1.5	Cent'l 5-in. vert.	Gasoline	30.2	.604	.013
19	45	325	1135	1.5	do.	Kerosene	29.5	.59	.013
20	75	228	1135	1.5	do.	Coal	1423.	28.5	.01
25	45	306	602	3.	Cent'l 7-in. vert.	Gasoline	21.3	.424	.001
26	45	306	602	3.	do.	Kerosene	20.8	.416	.011
27	75	212	602	3.	do.	Coal	1010.	20.2	.008

*Double-acting pump. †Thresher tank pump. ‡Engine would not operate successfully on kerosene. §Spray pump.

By assuming definite prices for the different fuels, still more direct comparison can be made; for instance, by assuming the price of gasoline to be 25 cents a gallon, kerosene 15 cents a gallon, and coal $5 a ton, the fuel costs per acre-foot on the 7-inch vertical centrifugal pump for the 50-foot lift would be $5.32 for gasoline, $3.11 for kerosene, and $2.51 for coal. Other similar comparisons can be made but on account of variations in prices it is considered inadvisable to elaborate further, especially since these costs are only for fuel and do not include engineer's salary and interest and depreciation on the plant.

CONCLUSIONS

Conditions in Montana so far have not been very favorable for the extensive development of pumping for irrigation. Some of the factors affecting this are the short growing season, the kinds of crops raised, the large amount of cheap land, the large farm units, the sparse population, high prices of materials, high wages, high freight rates, lack of competition, poor market facilities, and so forth. It is believed, however, that many of these factors are being rapidly modified and eliminated and that in the near future conditions will be on a basis more nearly equal to that of other arid and semiarid States. For instance, the crops raised by pumped water will be better adapted to Montana conditions; the large amount of cheap and grazing land is disappearing; the large farm units are being subdivided, the population is increasing very rapidly, and with these changed conditions pumping for irrigation is going to become more feasible, especially if cheap fuel or power can be obtained for pumping.

In Montana the heavy fuel oil engine has not been generally used for irrigation pumping, but with the development of new oil fields in this region the use of such engines may help to solve the fuel cost of pumping. The development and utilization of the large amount of water-power in the State and its conversion into electrical energy may also afford a source of cheap power for irrigation pumping. There are some steam plants in successful operation but the law makes necessary the employment of a licensed engineer. Most of the individual plants in the State use gasoline or kerosene engines for the motive power.

In the selection of a pumping plant there are some general instructions that will be of benefit. The necessary capacity of the

plant depends upon the kind of crop, the soil condition, the acreage, and the available water supply. If no storage is provided the rate of pumping should be great enough to furnish sufficient water with which to irrigate economically and this depends upon the crop, the soil, the condition of the land, and upon the irrigator. The manufacturer should guarantee the pump to deliver the required amount of water against the given head on a specified brake horse-power. The pump specifications should cover the suction and discharge pipes and connections, and the head on the pump in the specifications should be the total useful lift as determined in the field. If this cannot be determined definitely the specifications should be made to include several different heads, and the necessary speed of the pump for each head should be furnished by the pump manufacturer. The engine should be guaranteed to deliver the required brake horse-power at the site of the plant on a specified rate of fuel consumption, the quality of the fuel being indicated also.

The results of the laboratory tests bring out forcibly the inadvisability of using just any combination of power and pump that may be had upon a farm. They also indicate in a certain measure what kind of combinations should be made to secure an efficient plant. As an illustration of this, suppose a farmer has a tractor similar to the one used in these tests and he wishes to use it in pumping water for irrigation. If he has a 50-foot lift the use of this tractor with the 7-inch vertical pump would give a low fuel consumption as indicated in tests No. 25 and 26. These tests gave a fuel consumption of a little over 0.4 gallon per foot acre-foot which is very satisfactory. This same engine driving the 5-inch vertical pump with one-half the rate of discharge of the 7-inch pump had a fuel consumption of about 0.6 gallon per foot acre-foot or about 50 per cent greater fuel consumption as indicated in tests No. 18 and 19. Again, when this engine was driving the 3-inch pump on this lift the fuel consumption was about 1 gallon per foot acre-foot or nearly 2.5 times the amount required with the largest pump, and in addition to this the rate of pumping the water was only one-fifth of the rate with the largest pump. This is shown in tests No. 11 and 12.

If the lift is 25 feet, about the same ratios of fuel consumption exist for the three different pumps as indicated in tests No. 22 and 23,

16 and 17, and 8, but in this case the fuel consumption per foot acre-foot is about 50 per cent greater than that for the 50-foot lift. A larger pump than any of those tested should be used with this tractor on the 25-foot lift.

For another illustration, suppose the lift is only 10 feet. The tractor with the largest pump gave a fuel consumption of 1.22 gallons per foot acre-foot, as indicated in test No. 21. With a much larger pump designed for a low lift, the fuel consumption could have been kept down. In tests No. 6 and 14, where a 5-horse-power engine was used with a 3-inch and a 5-inch pump respectively, the fuel consumption was about 0.7 gallon per foot acre-foot. This is still a little high and better results were obtained in field tests No. 17 and 56, which were for lifts of 11.5 and 10 feet and the fuel consumption was 0.54 and 0.573 gallon per foot acre-foot respectively.

It is realized that many tests could be made to help solve the problem of economical pumping for irrigation, but the results herein given throw considerable light on the subject and show some of the reasons why some plants have proved to be failures. They indicate the necessity for careful designing of pumping plants and proper operation of the plant after it is installed.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION
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Dry Farm Crop Rotations and Cultural Methods

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Dry Farm Crop Rotations and Cultural Methods

This bulletin presents some of the data that have been obtained from the experiments with crop rotations and cultivation methods which were started at the Judith Basin Substation in 1908 and at the Huntley Experiment Station in 1912. The work here reported is all under dry land conditions. It is cooperative work between the Montana Experiment Station and the Bureau of Plant Industry of the United States Department of Agriculture.

The present publication is in the nature of a preliminary report giving the results of the first years after breaking prairie sod. While these conclusions may be changed by the results of succeeding years as the land becomes older, it is believed that they afford definite information on the results that may be expected under similar conditions, and should serve as guides in outlining cropping systems for the dry lands of this area as they are brought under cultivation.

LOCATION OF STATIONS

The Judith Basin Substation is located in Fergus County, two miles west of Moccasin, Montana, being almost in the center of the State. It is situated on one of the higher benches of the Judith Basin, with an altitude of 4,300 feet. The soil and general conditions are considered fairly representative of this area.

The Huntley Experiment Farm is located at Osborn, Montana, seventeen miles east of Billings, in Yellowstone County. The land used is situated between the main canal of the Huntley Reclamation Project and the foothills on the south of the Yellowstone Valley. The altitude is 3,000 feet.

CLIMATIC CONDITIONS

Climatic data, including precipitation, wind velocity, evaporation, and temperature, have been recorded at the Judith Basin Substation since 1909 and at the Huntley Experiment Station since 1911. These data have been obtained in cooperation with the Biophysical Laboratory, Bureau of Plant Industry, U. S. Department of Agriculture.

TABLE I.—Monthly, seasonal, and annual precipitation at Judith Basin for the period from 1898 to 1915, with maximum, minimum, and average monthly, seasonal, and annual, and the percentage of the seasonal to the annual.*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Seasonal	Percentage of seasonal to annual
1898	0.70	0.27	1.91	1.12	5.87	5.80	3.16	0.67	0.47	1.25	1.14	0.59	22.95	16.62	72.5
1899	1.69	.38	.92	2.29	3.33	1.22	2.57	1.31	.28	1.15	.11	.88	16.13	9.72	60.3
1900	.45	.35	.21	2.85	1.04	.44	.70	2.20	.82	.86	.29	.21	10.42	7.23	69.2
1901	.40	.20	.57	1.65	3.82	3.97	1.97	.90	2.42	1.39	T	3.22	20.51	12.31	60.0
1902	.14	.24	.45	1.12	1.41	3.28	1.84	.67	.32	.18	2.04	.25	11.94	8.32	69.5
1903	.50	.24	1.11	2.29	1.82	2.81	2.57	.81	2.42	.05	.44	.65	15.71	10.30	65.5
1904	.18	.22	.79	1.14	1.94	1.73	3.25	.42	.12	.54	.50	.24	11.07	8.48	76.4
1905	.19	.16	.62	.75	1.97	2.82	3.19	.27	.83	.39	.50	T	11.69	9.00	77.6
1906	.55	.63	.43	.16	2.61	2.66	.93	2.00	.99	.70	.42	.68	12.76	8.36	65.5
1907	1.34	.08	.61	.43	3.21	6.75	3.51	1.47	.73	.20	T	T	18.33	15.37	83.7
1908	.55	.49	.98	.61	7.31	2.45	.20	1.18	1.41	6.27	T	.22	21.67	11.75	54.2
1909	.90	.08	1.22	1.03	1.34	5.97	2.54	4.21	4.47	.49	.30	1.21	23.76	15.09	63.3
1910	.09	.74	.10	1.31	2.40	1.69	1.10	2.02	2.54	1.36	1.26	.48	15.08	8.52	56.7
1911	.58	.55	.54	1.66	2.98	2.55	.50	6.34	1.37	1.94	1.76	.66	21.45	14.23	66.4
1912	.88	.60	.81	1.43	3.94	0.64	1.92	1.27	1.63	1.68	.14	.06	15.00	9.20	61.3
1913	.89	.09	.20	.79	2.64	4.77	1.12	.51	1.01	1.63	.93	.38	14.96	9.83	65.8
1914	.47	1.35	1.12	1.19	2.91	4.64	.64	.65	1.11	.74	.64	.21	15.67	10.03	64.2
1915	.76	.08	2.69	1.43	2.12	3.77	3.54	.92	2.65	.85	1.01	.66	20.68	11.98	57.8
Ave.	.62	.38	.85	1.29	2.93	3.23	1.96	1.55	1.42	1.20	.64	.59	16.66	10.90	65.9
Max.	1.69	1.35	2.69	2.85	5.87	6.75	3.54	4.21	4.47	6.27	2.04	3.22	23.76	16.62	83.7
Min.	.09	.08	.10	.16	1.04	.44	.20	.27	.12	.05	T	T	10.42	7.23	54.2

*Data previous to 1909 from records of U. S. Weather Bureau at Utica, nine miles from station.

TABLE II.—Monthly, seasonal, and annual precipitation at Huntley for the period from 1907 to 1915, with maximum, minimum, and average monthly, seasonal, and annual, and the percentage of the seasonal to the annual.*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Seasonal	Percentage of seasonal to annual
1907	0.36	0.44	1.12	0.45	4.23	1.76	2.39	0.57	0.93	0.51	0.05	0.28	13.09	9.40	72.3
1908	.25	1.04	.69	1.03	4.85	1.47	.39	.94	1.51	1.80	.11	.25	14.33	8.68	60.1
1909	.49	.11	1.27	.90	2.56	1.99	1.33	.68	.80	.50	.65	.75	12.03	7.46	61.7
1910	.47	.62	.55	1.72	1.65	.92	00	1.00	2.73	1.36	1.21	.48	12.71	5.29	41.0
1911	.82	.14	.15	.85	3.29	2.13	.81	1.05	.57	.88	.89	.13	11.71	8.13	69.2
1912	.27	.21	.41	2.00	2.44	1.64	2.75	1.39	2.97	3.25	.75	00	18.08	10.22	56.7
1913	.29	.10	.40	.43	1.27	2.20	1.10	1.19	1.43	2.89	.45	.17	11.92	6.19	52.0
1914	.11	.19	.52	1.16	2.83	3.31	.05	.76	1.90	1.07	.07	.24	12.21	8.11	66.4
1915	.41	.02	.78	.23	2.50	5.99	3.11	.50	1.64	.31	1.34	.71	17.54	12.33	70.3
Ave.	.38	.32	.63	.97	2.85	2.38	1.32	.90	1.61	1.39	.61	.33	13.74	8.42	61.3
Max.	.82	1.04	1.27	2.00	4.85	5.99	3.11	1.39	2.97	3.25	1.34	.75	18.08	12.33	68.3
Min.	.11	.02	.15	.23	1.27	.92	00	.50	.57	.31	.05	00	11.71	5.29	44.5

*Data previous to 1910 from records of U. S. Weather Bureau at Huntley, four miles from station.

The records shown previous to 1909 for Judith Basin were taken by the U. S. Weather Bureau at Utica, nine miles from the station. Those shown previous to 1911 for Huntley were taken by the U. S. Weather Bureau at the town of Huntley, four miles from the station. In order to better interpret the crop results, certain climatic data will be presented.

Precipitation.—Table I shows the precipitation by months and the total annual precipitation for eighteen years at Judith Basin. Table II shows the same data for nine years at Huntley. The seasonal precipitation (the total from April to August) is shown for each year with the percentage of seasonal to total. The average, the minimum, and the maximum for each month for the entire period at each station are also shown.

Table I shows the average annual precipitation for Judith Basin to be 16.66 inches, with a minimum of 10.42 inches and a maximum of 23.76 inches. Table II shows that at Huntley the average annual precipitation has been 13.74 inches, with a minimum of 11.71 inches and a maximum of 18.08 inches.

The seasonal rainfall, April to August inclusive, shows even more variation than the annual. At Judith Basin the average is 10.90 inches, with a maximum of 16.62 inches in 1898 and a minimum of 7.32 inches in 1900. At Huntley the average seasonal rainfall is 8.42 inches, the maximum being 12.33 inches in 1915 and the minimum 5.29 inches in 1910. The percentage of seasonal to annual rainfall varies at Judith Basin from 54.2 in 1908 to 83.7 in 1907, with an average of 65.9. At Huntley this percentage varies from 41.0 in 1910 to 70.3 in 1915, with an average of 61.3.

At both places May and June are the months of highest rainfall, June with an average of 3.23 inches being the highest at Judith Basin, and May with an average of 2.85 inches being the highest at Huntley.

Wind velocity.—Table III shows the average hourly wind velocity from April to October 1st, giving the average for each month each year and the average for each month for all years at each station. The data are shown from 1910 to 1915, inclusive, at Judith Basin and from 1911 to 1915, inclusive, at Huntley. The velocity was recorded by anemometers two feet from the surface of the ground.

TABLE III.—Average hourly wind velocity at Judith Basin and at Huntley each month from April to September, inclusive, with the seasonal average each year and the monthly average for the entire period of years. (Miles per hour.)

Year	Apr.	May	June	July	Aug.	Sept.	Average
			Judith Basin				
1910	9.9	6.8	6.3	5.9	6.0	4.0	6.3
1911	7.8	8.0	5.4	5.9	5.9	5.3	6.4
1912	6.6	7.6	5.7	4.3	6.4	6.7	6.4
1913	8.7	6.5	5.3	5.0	5.4	6.5	6.2
1914	....	7.5	6.4	5.5	6.0	7.2	6.5
1915	7.6	7.5	6.6	5.1	4.9	5.9	6.3
Ave.	7.7	7.3	6.0	5.4	5.8	5.9	6.3
			Huntley				
1911	....	5.5	4.4	4.6	4.1	4.3	4.6
1912	5.8	6.3	5.2	3.9	3.7	4.2	4.8
1913	....	4.5	3.8	3.7	3.2	3.6	3.8
1914	5.1	4.0	3.2	2.7	3.2	3.5	3.6
1915	4.2	5.0	3.9	3.1	2.3	3.4	3.6
Ave.	5.0	5.1	4.1	3.6	3.3	3.8	4.1

The data show the average hourly wind velocity for this period to be 50 per cent greater at Judith Basin than at Huntley. The highest monthly average for each station is for April.

Temperature.—Table IV gives the average mean temperature by months from April 1 to September 30 at Judith Basin from 1909 to 1915, inclusive, and at Huntley from 1911 to 1915, inclusive. The table shows that the average mean temperature for this period at Huntley was 59.7 degrees compared with 54.8 degrees at Judith Basin. The greatest monthly difference between the mean temperatures of the two stations is in June.

TABLE IV.—Mean monthly temperatures for the months from April to September, inclusive, for the period from 1909 to 1915 at Judith Basin, and from 1911 to 1915 at Huntley.

	April	May	June	July	August	Sept.	Average
Judith Basin	43.0	49.4	58.3	63.6	63.3	52.0	54.8
Huntley	45.0	54.6	64.5	68.5	67.5	55.1	59.7

Evaporation.—Table V shows the monthly evaporation in inches from a free-water surface during the interval from April 1 to August 31 for the years 1909 to 1915, inclusive, at Judith Basin, and from May 1 to August 31 for the years 1911 to 1915, inclusive, at Huntley. The data were obtained from a tank six feet in diameter which was sunk into the ground to a depth that brought the water level even with the surface of the ground. The monthly averages for each station do not show significant differences between the stations. Those for May and June are slightly the higher at Judith Basin, while the averages for June and July are the higher at Huntley.

A summary of available climatic data for the two stations shows that the total annual precipitation, the seasonal precipitation, and the percentage of seasonal to annual precipitation are greater at Judith Basin than at Huntley. The wind velocity for the growing season is 50 per cent greater at Judith Basin than at Huntley. The mean temperature from April 1 to October 1 is 5 degrees higher at Huntley than at Judith Basin. The frost-free period at Huntley

TABLE V.—Monthly evaporation in inches from a free water surface, with the total for each season and the average for each month. For the months April to August and the years 1909 to 1915 at Judith Basin and for the months May to August and the years 1911 to 1915 at Huntley.

Year	April	May	June	July	August	Total
			Judith Basin			
1909	3.000	4.657	5.997	7.222	7.060	27.936
1910	5.176	5.606	7.208	8.283	7.382	33.655
1911	4.097	5.941	5.128	7.312	6.352	28.830
1912	2.618	4.140	6.394	5.965	6.231	25.348
1913	3.890	4.220	4.900	6.360	7.350	26.720
1914	3.208	4.845	4.431	7.450	7.239	27.173
1915	4.697	4.612	4.345	4.890	6.505	25.049
Average	3.812	4.860	5.486	6.640	6.875	
			Huntley			
1911		5.827	7.124	8.875	6.061	27.887
1912		4.090	7.020	6.942	6.959	25.011
1913		4.298	5.976	7.020	6.304	23.589
1914		4.336	4.936	7.778	7.216	24.266
1915		4.304	4.582	5.493	6.018	20.397
Average		4.571	5.928	7.222	6.512	

is from ten to fourteen days longer than at Judith Basin. The difference in evaporation between the two stations is not significant.

Soils.—At Judith Basin the soil is a dark clay loam, varying in depth from 3 inches to 3 feet. The subsoil is a limestone gravel intermixed with clay to a depth of 30 feet. Because of its formation, the water-holding capacity of this soil is limited.

At Huntley the surface soil is a medium heavy, silty clay loam to a depth of 1 foot. Below this to a depth of approximately 4 feet the soil is a heavy clay, and the fifth and sixth feet contain slightly more sand. The character of this soil is such that a large amount of moisture can be stored.

TABLE VI.—Mechanical analyses of soils at Judith Basin and at Huntley by Bureau of Soils, U. S. Department of Agriculture (expressed in per cent).

Depth in feet	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to .1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0 mm.)
				Judith Basin			
1	9.0	2.7	4.4	13.3	13.4	40.7	24.3
2	1.1	2.3	3.2	10.4	11.6	33.3	38.1
				Huntley			
1	0	0.2	0.9	10.2	21.9	45.8	20.9
2	0	.2	.6	8.9	23.4	46.6	20.1
3	0	.2	1.0	12.4	22.9	43.2	20.4
4	0	.2	1.1	13.7	24.4	39.6	20.9
5	0	.1	.7	11.7	20.6	41.7	25.3
6	0	.2	1.2	20.1	28.9	32.0	17.3

Table VI shows the mechanical analysis of the soils at Judith Basin to a depth of 2 feet and of the soils at Huntley to a depth of 6 feet. The table shows that at both places the percentages of silt and clay are high. This accounts in part for the adhesiveness of these soils when they are wet.

The soils at both places are at present in a good state of fertility as is shown by their production in seasons when the needs of the crop for water are met.

Tables VII and VIII give the results of analyses of the soils at each station by the Bureau of Soils of the U. S. Department of Agriculture.

TABLE VII.—Chemical analysis of soil at Judith Basin by Bureau of Soils, U. S. Department of Agriculture.

	First foot Parts per 100,000	Second foot Parts per 100,000
Magnesium (Mg)	40	40
Sulphates (SO_4)	30	30
Chlorides (Cl)	280	....
Bicarbonates (HCO_3)	190	190
Phosphates (PO_4)	trace	trace
Nitrogen	220	150
Total solids by evaporation	744	488
Per cent of soil	0.744	0.488
Per cent of nitrogen	0.220	0.150

TABLE VIII.—Chemical analysis of soil at Huntley by Bureau of Soils, U. S. Department of Agriculture (expressed in per cent).

	1st ft.	2nd ft.	3rd ft.	4th ft.	5th ft.	6th ft.
Potash (K_2O)	1.80	2.40	1.68	1.96	2.10	1.60
Phosphate (P_2O_5)	.46	1.12	.56	.62	.75	.52
Calcium (CaO)	1.86	1.91	2.40	2.29	2.46	2.79
Nitrogen (N)	.14	.15	.09	.09	.07	.05

COST OF PRODUCTION

It is readily seen that in the comparison of yields from different cropping systems containing different crops and combinations of crops, a common term of expression is necessary. For instance, the yields obtained from a rotation of wheat, oats, and corn can not be directly compared with the yields obtained from barley on continuous cropping. While the yields of the same crop grown under different methods of seed-bed preparation are directly comparable in bushels per acre, the profits from the different methods may show an entirely different relation to each other. For example, two methods may produce the same yield, but one of them, because of greater labor cost, may show decidedly less profit.

For the purpose of general comparison and in order to show

the results more from a practical point of view, a market price for each of the different crops and the cost of producing each crop by each method of seed-bed preparation is given. It is obvious that both the market price of the grain and the cost of production will vary with local conditions.

Table IX gives the average price for the past ten years of wheat, oats, barley, corn, and flax in the farm granary, for the states of North Dakota, South Dakota, Nebraska, and Kansas. The average for these four states is compared with the average price for the same crops for Montana during the same period. On the lower line are shown the figures which are used in the computations in this bulletin. These represent the market value minus the cost of threshing, or the market price in the field.

It will be noted that the prices of oats, barley, and corn in Montana during the past ten years have been higher than in the older markets. This is thought to be due to rather an unstable condition produced by the demands of mining camps and new settlers. As long as these local conditions prevail the crops mentioned will have an advantage, but it is believed that this area will soon be producing enough of these crops to more than supply the local demand. The prices used are based, therefore, on those of older settled communities where economic conditions are on a more stable basis.

As before stated, the cost of the various operations necessary

TABLE IX.—Average price at the farm granary for ten years of the principal crops in North Dakota, South Dakota, Nebraska, Kansas, and Montana, and the prices used in this study.

State	Wheat	Oats	Barley	Corn	Flax
North Dakota*	$0.82	$0.33	$0.47	$0.52	$1.34
South Dakota	.81	.33	.50	.44	1.31
Nebraska	.78	.34	.44	.45	1.28
Kansas	.82	.39	.47	.51	1.24
Ave. four states	.80¾	.34¾	.47	.48	1.29½
Montana	.77	.42	.58	.78	1.29
Used in this study**	.70	.30	.41	.40	1.10

*Taken from U. S. Department of Agriculture Yearbook, 1915.

**These prices represent the market price in the shock, the price of threshing being deducted from the market price in the granary.

in seed-bed preparation varies greatly, according to the individual equipment, the climatic conditions, and the character of the soil. In arriving at a final figure for the average cost of production, $2 a day has been allowed for a man and $1 a day for a horse. It is believed that these figures are sufficiently large to allow a fair labor income to the farmer.

Table X shows the acre-cost of the various farm operations, as used in determining the cost of production for the various crops. The force employed in man or horse-labor and the area included in a day's work are shown. From these is determined the cost per acre.

Using the unit cost of each operation as given in Table X, the comparative cost of producing each crop by each of the methods

TABLE X.—Average cost per acre of the farm operations involved in crop production in Montana. (The wage scale assumed is $2 a day for each man and $1 a day for each horse.)

Operation	Force employed Men	Force employed Horses	Day's work Acres	Item cost	Cost per acre
Plowing	1	4	3½		$1.71
Listing	1	4	10		.60
Subsoiling	1	3	3½		1.43
Disking	1	4	8		.75
Harrowing	1	4	35		.17
Drilling	1	4	15		.40
Planting corn	1	2	15		.25
Cultivating corn	1	4	16		.38
Manuring	1	2	1¼		3.20
Harvesting small grain					
Cutting	1	4	15	$.40	
Shocking	1			.13	
Twine				.25	.93
Binder depreciation				.15	
Harvesting flax					
Cutting	1	4	15	.40	.65
Binder depreciation				.15	
Harvesting corn					
Cutting	1	3	8	.62½	
Shocking	2			.50	1.50
Twine				.22½	
Binder depreciation				.15	

under trial has been computed and is given in Table XI. This shows the number of each of the operations actually performed in producing the several crops by each of the methods under trial, their cost, the cost of seed, a charge of $1.60 per acre to cover rental or taxes and interest on a valuation of $20 per acre, and the total cost of production expressed both in dollars per acre and in bushels per acre. This is the cost in the shock, which is the point where the acre basis of cost ends, further cost being based entirely on yield. The values of the crops have been computed at this point, deductions to cover the cost of completing their harvest and of storage having been made from the farm price.

GENERAL PLAN OF THE INVESTIGATIONS

The experimental work has been conducted on the same general plan at both stations. Standard crops have been grown both in rotations and by different methods of seed-bed preparation under systems of continuous cropping.

Figures 1 and 2 show diagrams of the fields laid out for this study at Judith Basin and at Huntley. The plats are one-tenth acre in size, being 2 rods wide by 8 rods long. They are separated by bare alleys 4 feet wide along their sides and roadways 20 feet wide between the ends of the plats. Rotations requiring from two to six years to complete one cycle are used at each station. At Judith Basin six crops and at Huntley five crops are represented

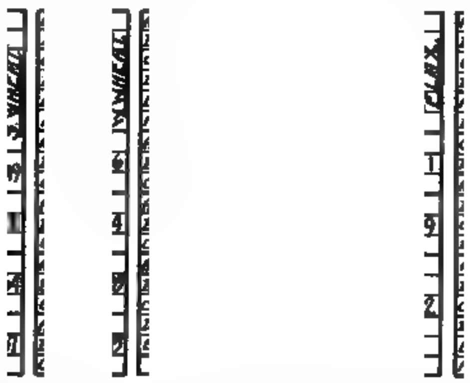

FIG. 1. Plan of work at Judith Basin with crops as they were grown in 1915. S. P.=spring plowed, F. P.=fall plowed, D. C.=disked corn land, S. S.=subsoiled, L.=listed, G. M.=green manure, S. F.=summer fallowed, M.=barnyard manure.

TABLE XI.—Cost per acre of producing each crop in the shock.

Crop and method of seed-bed preparation	Number of plowings	Cost of plowing	Number of diskings	Cost of disking	Number of harrowings	Cost of harrowing	Number of cultivations	Cost of cultivation	Cost of drilling	Cost of seed	Cost of harvesting	Interest and taxes	Total cost of production in dollars per acre	Total cost of production in bushels per acre
Wheat														
Spring plowed	1	$1.71	2	$1.50	2	$0.34			$0.40	$0.85	$0.93	$1.60	$7.33	10.5
Fall plowed	1	1.71	2	1.50	2	.34			.40	.85	.93	1.60	7.33	10.5
Disked land			2	1.50	2	.34			.40	.85	.93	1.60	5.62	8.0
Fallowed	1	1.71	4	3.00	5	.85			.40	.85	.93	3.20	10.94	15.6
Green manure (rye)*	2	3.42	3	2.25	8	1.36			.80	1.85	.93	3.20	13.81	19.7
Green manure (peas)**	2	3.42	3	2.25	8	1.36			.80	4.85	.93	3.20	16.81	24.0
Subsoiled†	1	1.71	2	1.50	2	.34			.40	.85	.93	1.60	8.76	12.5
Listed‡			2	1.50	2	.34			.40	.85	.93	1.60	6.22	8.9
Oats														
Spring plowed	1	1.71	2	1.50	2	.34			.40	.60	.93	1.60	7.08	23.6
Fall plowed	1	1.71	2	1.50	2	.34			.40	.60	.93	1.60	7.08	23.6
Disked land			2	1.50	2	.34			.40	.60	.93	1.60	5.37	17.9
Fallowed	1	1.71	4	3.00	5	.85			.40	.60	.93	3.20	10.69	35.6
Green manure (rye)*	2	3.42	3	2.25	8	1.36			.80	1.60	.93	3.20	13.56	45.2
Green manure (peas)**	2	3.42	3	2.25	8	1.36			.80	4.60	.93	3.20	16.56	55.2
Subsoiled†	1	1.71	2	1.50	2	.34			.40	.60	.93	1.60	8.51	28.3
Listed‡			2	1.50	2	.34			.40	.60	.93	1.60	5.97	19.9

*$1 per acre is charged for rye seed for green manure. **$4 per acre is charged for pea seed for green manure. †$1.43 per acre is charged for subsoiling. ‡$0.60 per acre is charged for listing.

TABLE XI (Continued).—Cost per acre of producing each crop in the shock.

Crop and method of seed-bed preparation	Number of plowings	Cost of plowing	Number of diskings	Cost of disking	Number of harrowings	Cost of harrowing	Number of cultivations	Cost of cultivation	Cost of drilling	Cost of seed	Cost of harvesting	Interest and taxes	Total cost of production in dollars per acre	Total cost of production in bushels per acre
Barley														
Spring plowed	1	1.71	2	1.50	2	.34			.40	.75	.93	1.60	7.23	17.8
Fall plowed	1	1.71	2	1.50	2	.34			.40	.75	.93	1.60	7.23	17.8
Disked land			2	1.50	2	.34			.40	.75	.93	1.60	5.52	13.8
Fallowed	1	1.71	4	3.00	5	.85			.40	.75	.93	3.20	10.84	26.5
Green manure (rye)*	2	3.42	3	2.25	9	1.36			.80	1.75	.93	3.20	13.71	33.4
Green manure (peas)**	2	3.42	3	2.25	9	1.36			.80	4.75	.93	3.20	16.71	40.8
Subsoiled†	1	1.71	2	1.50	2	.34			.40	.75	.93	1.60	8.66	21.1
Listed‡			2	1.50	2	.34			.40	.75	.93	1.60	6.12	15.0
Flax														
Spring plowed	1	1.71	2	1.50	2	.34			.40	.50	.65	1.60	6.70	6.0
Fall plowed	1	1.71	2	1.50	2	.34			.40	.50	.65	1.60	6.70	6.0
Disked land			2	1.50	2	.34			.40	.50	.65	1.60	4.99	4.5
Fallowed	1	1.71	4	3.00	5	.85			.40	.50	.65	3.20	10.31	9.3
Corn														
Spring plowed	1	1.71	2	1.50	2	.34	3	$1.14	.25	.22	1.50	1.60	8.26	20.6
Fall plowed	1	1.71	2	1.50	2	.34	3	1.14	.25	.22	1.50	1.60	8.26	20.6
Fallowed	1	1.71	4	3.00	5	.85	3	1.14	.25	.22	1.50	3.20	11.87	29.7
Subsoiled	1	1.71	2	1.50	2	.34		1.14	.25	.22	1.50	1.60	9.69	24.2
Listed					1	.17	3	1.14	.60	.22	1.50	1.60	5.23	13.1

*$1 per acre is charged for rye seed for green manure. **$4 per acre is charged for pea seed for green manure. †$1.43 per acre is charged for subsoiling. ‡$0.60 per acre is charged for listing.

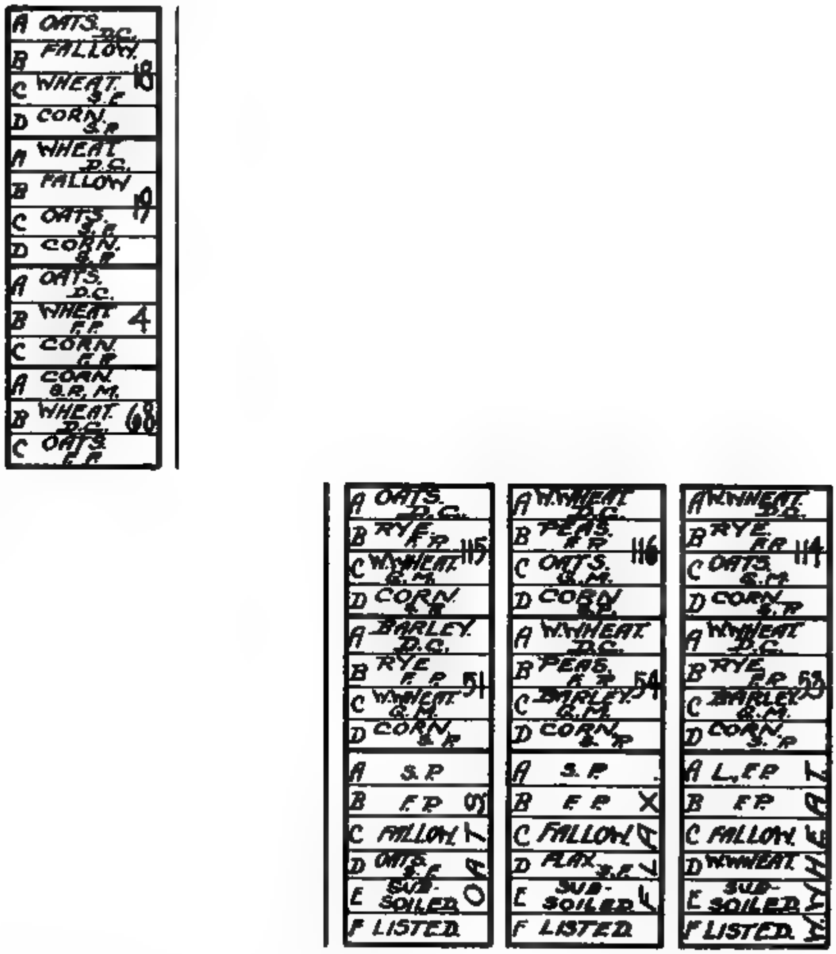

FIG. 2. Plan of work at Huntley with crops as they were grown in 1915. S. P.=spring plowed, F. P.=fall plowed, D. C.=disked corn land, S. S.=subsoiled, L.=listed, G. M.=green manure, S. F.=summer fallowed, M.=barnyard manure.

in a series of continuously cropped plats lettered from A to F or G. In the diagram the crop is indicated by the name written across the plat. Plats C and D are alternately cropped and summer fallowed. Each season one plat is cropped and the other fallowed. The other plats in these series are planted continuously to the same crop, each plat having different tillage.

On the diagrams the different rotations and cropping series are separated by heavy lines. Each rotation has a number and each plat within the rotation is lettered, beginning at A and including as many letters as there are plats. Each rotation contains as many plats as the number of years necessary to complete the cycle of the rotation. In this way each crop and each method are represented each year and thus subjected to the same climatic conditions. The crops rotate one plat each year, moving from Z to A. Thus, a three-year rotation would contain three plats, lettered A, B, and C. The crop that was on plat A in 1915, will move to plat C in 1916, the crop that was on plat B in 1915 will move to A in 1916, and the crop that was on plat C in 1915 will move to B in 1916.

In figures 1 and 2 the diagrams are filled out to show the cropping in 1915. The letters following the crop indicate the treatment given the ground in preparation for the crop shown; thus, S. P. stands for spring plowed, F. P. for fall plowed, D. C. for disked corn land, S. S. for subsoiled, L. for listed, G. M. for green manure, and S. F. for summer fallowed. The addition of the letter M indicates the use of barnyard manure. To illustrate: In 1915, rotation No. 16 had wheat on disked corn land in plat A; peas on fall plowing, to be turned under for green manure, in plat B; oats on green-manured land in plat C, and corn on spring plowing in plat D. In 1916, A will be in peas, B in oats, C in corn, and D in wheat.

The methods of operation have been similar at the two stations. Fall plowing is done as soon as practicable after the previous crops are taken off. This allows much earlier plowing after small grain than after corn. All plowing is done to a depth of 7 inches at Judith Basin and 8 inches at Huntley, except plat A in each of the continuous-cropping series. This plat is plowed 4 inches deep at both stations. Fall plowing is usually left rough through the winter except where fall grain is to be sown.

Spring plowing for small grain is done as early in the spring as soil conditions will permit. Spring plowing for corn is done just previous to planting.

Listing for small grain is done at the same time as fall plowing, and except when it is a preparation for winter wheat is left furrowed through the winter. For winter wheat the land is leveled just before seeding. Listing for corn is done in the spring.

The plats to be subsoiled are fall plowed to the usual depth. The subsoil plow follows in the same furrow. At Huntley the soil is stirred to a total depth of about 14 inches. At Judith Basin where the subsoil is gravelly the total depth is about 10 inches.

Where crops are seeded on disked land, the disking is usually done just before seeding.

Plats to be fallowed are plowed in May or early in June and given sufficient subsequent cultivation to prevent weed growth during the remainder of the season.

Where green manure is used, the ground is fall plowed for the crop to be used. These crops are then plowed under when they have attained maximum growth. After that the land is treated the same as fallow.

Following the sod crops—brome and alfalfa—it has been necessary at both stations to plow twice in order to subdue the soil. The land is first plowed about 3 inches deep and later about 7 or 8 inches. Even by this method neither of these sod crops has been completely killed.

After plowing, all plats are given sufficient cultivation to prepare a good seed-bed. Plats having the same method of seed-bed preparation are given uniform cultivation.

The crops grown, as well as the varieties used, have been those

TABLE XII.—Crops grown, with rate of seeding and varieties, at Judith Basin and Huntley.

Crop	Rate of seeding per acre	Varieties used at	
		Judith Basin	Huntley
Winter wheat...	3 pks.	Kharkov	Kharkov
Spring wheat....	1 bu.	Kubanka	Kubanka
Oats....	1½ bus.	Sixty Day	Sixty Day
Barley....	1 bu.	White Hulless	Guy Mayle (hullless)
			White Smyrna (hulled)*
Corn....	**	Northwestern Dent	Northwestern Dent
Flax....	25 lbs.	Common	Minnesota No. 25
Brome grass....	14 lbs.	Common	Common
Alfalfa....	10 lbs.	Montana	Montana
Clover....	15 lbs.	Common	

*The hulled barley has been seeded at the rate of 1½ bushels per acre.
**The corn was drilled in rows 44 inches apart.

that experience has shown to be adapted to the locality. The general plan is to use the same variety continuously at one station. Changes are made only when experience shows that another variety is decidedly superior. At each station all plats to be seeded to the same crop are seeded, as nearly as possible, on the same date. Each crop has been seeded at the same rate per acre at both stations. All small grain has been seeded with a drill and the corn seeded with a corn planter.

Table XII shows the crops that have been grown under the various treatments, with the rate of seeding and the varieties used.

CROP ROTATIONS

A crop rotation is a system of cropping in which crops follow each other in a regular sequence according to a prearranged plan, as distinguished from continuous cropping to the same crop, or from miscellaneous cropping as planned from year to year.

The rotation work here reported was planned to study the effect of growing the crops in different combinations and under different methods of tillage. Some rotations are calculated to increase the organic matter in the soil, by the growth of sod crops, by turning under crops of green manure, or by the addition of barnyard manure. In other rotations all crops are taken off and no attempt made to meet any loss of organic matter.

The data here reported from Judith Basin are from twenty-seven different cropping systems, including two 2-year, thirteen 3-year, six 4-year, two 5-year, and two 6-year rotations. The results from Huntley are from twenty-nine different cropping systems, including one 2-year, ten 3-year, sixteen 4-year, and two 6-year rotations.

These rotations divide themselves into rather definite groups.

Group I contains 2-year rotations comparing fallow with corn land as a preparation for spring wheat and oats.

Group II contains 3-year rotations containing two of the spring grain crops, wheat, oats, or barley, and either corn or fallow in the third year. The small grain is grown on spring plowing, fall plowing, or disked corn land. Corn is on either spring or fall plowing.

Group III includes 3- and 4-year rotations containing one crop which is plowed under for green manure. This crop may be rye, peas, or sweet clover. In both the 3- and 4-year rotations a small grain crop follows the green manure crop, and corn follows small

grain. In the 4-year rotations another small grain crop comes between the corn and the green manure crop. Other rotations in this group contain a bare fallow for comparison with green manure.

Group IV contains 5- and 6-year rotations comparing different sod crops and their effect on the following crops.

A complete discussion, with comparisons, of the crops grown in the different systems included in this work is impossible in a publication of this character.

In the tables which follow the rotations are classed by groups and the discussions are limited to the more important comparisons within each group. The annual per-acre yields are shown with the average for each crop within a rotation. From the average yield the income per year is obtained by multiplying this average yield by the average bushel price for the crop as shown in Table IX. The cost of production, which varies with the different methods of preparation, is then deducted from the income. The figures for the cost of production are shown in Tables X and XI. The sum of the profits or losses from each group gives the profits for the rotation. As all the data are on an acre basis and as there are as many plats in a rotation as there are years in a system, this total is divided by the number of years in the system to obtain the profits or losses on an annual acre basis.

GROUP I

This group contains two 2-year rotations—No. 49, corn on fall plowing followed by wheat on disked corn land; and No. 40, corn on fall plowing followed by oats on disked corn land. With these rotations are compared the two plats, C and D, alternately cropped and summer fallowed in the continuous cropping series of wheat and oats, This gives a direct comparison of corn and fallow as a preparation for these two crops.

A comparison of the yields presented in Table XIII shows that in rotation No. 49 the average yield of wheat following corn was 1.7 bushels more at Judith Basin and practically the same at Huntley as that of wheat following summer fallow. In addition to the wheat, the rotation containing corn produced an average of 2.7 tons of fodder at Judith Basin and 25.5 bushels of corn and 1,620 pounds of stover at Huntley. When the value of the corn crop is considered,

TABLE XIII.—Yields, income, cost of production, and profits per acre of rotations in Group I, comparing fallow with corn land as a preparation for spring wheat and oats.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Judith Basin								
49	Wheat	..Disked corn	35.6	7.4	25.8	*	26.0	17.0	32.8	24.1	$16.87	$5.62	$11.25		
	Corn	....F. plowing	5.3	1.5	3.4	*	1.6	2.3	2.2	2.7	10.80	8.26	2.54	$13.79	$6.89
							Huntley								
49	Wheat	..Disked corn					19.0	22.8	37.6	26.5	18.55	5.62	12.93		
	Corn	....F. plowing					†16.8	†23.8	†35.8	†25.5	10.20				
							‡1600	‡1830	‡1430	‡1620	3.24	8.26	5.18	18.11	9.05
							Judith Basin								
C	Wheat	..Fallow	34.0	6.4	19.1	*	22.3	18.3	34.6	22.4	15.68	10.94	4.74		
	Fallow	..	..	..	..	..	..	..	..	....	....	....	....	4.74	2.37
							Huntley								
D	Wheat	..Fallow					22.6	19.5	36.5	26.2	18.34	10.94	7.40		
	Fallow	..					..	..	..	....	....	....	....	7.40	3.70
							Judith Basin								
40	Corn	....F. plowing	5.1	1.5	3.6	*	2.3	2.1	3.1	2.9	11.60	8.26	3.34		
	Oats	....Disked corn	68.9	25.0	57.0	*	76.9	50.9	83.1	60.3	18.09	5.37	12.72	16.06	8.03
							Huntley								
40	Corn	....F. plowing					†18.8	†13.3	†36.7	†22.9					
							‡1150	‡1870	‡1880	‡1500	12.16	8.26	4.90		
	Oats	....Disked corn					44.3	60.6	81.4	62.1	18.63	5.37	13.26	18.16	9.08
							Judith Basin								
C	Oats	....Fallow	78.7	25.8	65.9	*	78.4	61.5	82.8	65.6	19.68	10.68	9.00		
	Fallow	..	..	..	..	..	..	..	..	....	....	....	....	9.00	4.50
							Huntley								
D	Oats	....Fallow					64.6	40.3	101.9	68.9	20.67	10.68	9.99		
	Fallow	..					..	..	..	....	....	....	....	9.99	4.99

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover.

FIG. 3. Annual profits per acre for rotations in Group I. C.=corn, O.=oats, W.=wheat, F. P.=fall plowing, Fal.=fallow.

much greater profit is obtained where corn replaces bare fallow as a preparation for spring wheat.

The data from rotation No. 40, comparing alternating oats and corn with alternating oats and fallow, show that the average yield of oats was a few bushels higher after fallow than after corn at each station. When the value of the corn and fodder is considered with the cost of production, oats and corn show much greater profit than oats and fallow. The increase in yield after fallow was not sufficient to overcome the profit derived from the corn crop.

Figure 3 shows graphically the average annual profits of Group I as shown in Table XIII. At Huntley corn and oats were as profitable and at Judith Basin more profitable than corn and wheat. The chart brings out very clearly the increased profit from using corn instead of bare fallow as a preparation for spring wheat and oats. Where the farmer can utilize the feed produced by growing corn, it appears that summer fallow is not a practical preparation for spring-sown small grains.

GROUP II

This group contains eleven 3-year rotations. Each rotation contains two small grain crops and either corn or summer fallow in the third year. The crops included are spring wheat, oats, barley, and corn. These are grown in different combinations and under different cultural treatments. In two rotations, numbered 5 and 8, corn is replaced by summer fallow. In the rotations numbered 67 and 68, barnyard manure is applied to the small grain stubble previous to plowing for corn.

Rotation No. 1 shows that wheat on disked corn land has a decided advantage over the other crops at both stations. This is due in part to the greater income from this crop and in part to a lower production cost. The corn in this case is in part a preparation for the wheat. The average profit from the oats and corn combined is less at both stations than the profit from wheat.

Rotation No. 2 in Table XIV shows a lower average acre profit than is shown for rotation No. 1. The crops and the crop sequence are the same. The only difference is in the preparation for the crops. The average yields of wheat are a little lower for both stations where the wheat is grown on spring plowing than where it is grown on disked corn land. The greatest difference, however, is in the

cost of production, which is considerably less in rotation No. 1. The profits from the oats and corn at Huntley are a little higher on spring plowing than on fall plowing. At Judith Basin there is little difference in the profits from oats, but the profit from the corn crop is higher on spring plowing. This overcomes a portion of the increased cost of plowing the land for wheat in rotation No. 2.

The crops and crop sequence are the same in rotation No. 3 as in Nos. 1 and 2, but all of the crops are grown on fall plowing. The yields of wheat are a little lower than in rotation No. 1, where wheat is grown on disked corn land. There is, however, very little difference in the yields of any of the crops. The average annual acre profits are a little less than from rotation No. 1.

Rotation No. 4 differs from rotation No. 1 in that the oats are grown after the corn on disked corn land and the wheat follows the oats on fall plowing. In this case the oats are the most profitable crop, while in each of the three preceding rotations wheat was the most profitable. The advantage of the oat crop in this rotation is due in part to the high yield obtained by growing the oats on disked corn land and in part to the lower cost of seed-bed preparation. In average profits per acre there is no significant difference between this rotation and No. 1, the profit per acre being a little higher for rotation No. 4 at Judith Basin and a little higher for rotation No. 1 at Huntley.

In rotation No. 5 the small grains have the same sequence as in rotations Nos. 1, 2, and 3, with clean fallow taking the place of corn in the third year. The profits from the wheat, as well as the cost of production, are for one plat for two years. The yield of wheat on fallow at Judith Basin has not been materially more than on corn ground. While the yield of wheat was not materially increased by growing it on fallow land, the cost of production was materially increased. Consequently the profit from this rotation at Judith Basin is comparatively low. At Huntley the wheat on fallow gave quite material increase in yields but not enough to balance the increased cost of production, as is shown in the profits per acre from this rotation compared with the preceding rotations.

Rotation No. 6 is similar to rotation No. 1. The only difference is that wheat in rotation No. 1 is replaced by barley in this rotation. A direct comparison of this rotation with No. 1 shows that barley

TABLE XIV.—Yields, income, cost of production and profits per acre of the rotations in Group II, comprising three-year rotations containing two of the spring grain crops and either corn or fallow in the third year.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Judith Basin								
1	S. wheat	.Disked corn	34.8	11.7	28.0	*	24.0	21.6	33.8	25.6	$17.92	$5.62	$12.30		
	Oats	....F. plowing	68.1	21.2	50.6	*	57.8	51.2	63.1	52.0	15.60	7.08	8.52		
	Corn	....F. plowing	5.1	1.5	3.3	*	2.7	2.3	3.4	2.9	10.40	8.26	2.14	$22.96	$7.65
							Huntley								
1	S. wheat	.Disked corn					18.6	25.2	42.3	28.7	20.09	5.62	14.47		
	Oats	....F. plowing					32.1	52.8	59.4	48.1	14.43	7.08	7.35		
	Corn	....F. plowing					†20.2	†18.7	†41.2	†26.7	10.68				
							‡1450	‡1370	‡1560	‡1460	2.92	8.26	5.34	27.16	9.05
							Judith Basin								
2	S. wheat	.S. plowing	33.1	11.6	21.3	*	23.8	18.5	31.8	23.3	16.31	7.33	8.98		
	Oats	....S. plowing	63.1	25.3	51.5	*	54.5	45.3	67.1	51.5	15.33	7.08	8.25		
	Corn	....S. plowing	4.1	1.5	3.3	*	2.7	2.3	3.4	2.9	11.60	8.26	3.34	20.57	6.86
							Huntley								
2	S. wheat	.S. plowing					18.6	24.6	34.8	26.0	18.20	7.33	10.87		
	Oats	... S. plowing					42.8	55.6	51.9	50.1	15.03	7.08	7.95		
	Corn	....S. plowing					†28.1	†24.0	†34.7	†28.9	11.56				
							‡1650	‡1740	‡1680	‡1690	3.38	8.26	6.68	25.49	8.50
							Judith Basin								
3	S. wheat	.F. plowing	31.0	15.0	22.3	*	26.3	18.5	28.5	23.6	16.52	7.33	9.19		
	Oats	....F. plowing	61.5	17.5	49.6	*	55.6	56.2	65.9	51.0	15.30	7.08	8.22		
	Corn	....F. plowing	5.6	1.3	2.9	*	2.1	1.9	3.2	2.8	11.20	8.26	2.94	20.35	6.78

Corn fodder at Judith Basin in tons per acre Corn stover at Huntley in pounds per acre.
*Hailed out. †Grain. ‡Stover.

TABLE XIV (Continued).—Yields, income, cost of production, and profits per acre of the rotations in Group II, comprising three-year rotations containing two of the spring grain crops and either corn or fallow in the third year.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Huntley								
3	S. wheat	F. plowing					19.3	21.5	38.8	26.5	18.55	7.33	11.22		
	Oats	F. plowing					42.4	51.3	59.4	51.0	15.30	7.08	8.22		
	Corn	F. plowing					†20.1	†22.2	†39.8	†27.4	10.96				
							‡900	‡1370	‡1620	‡1297	2.59	8.26	5.29	24.73	8.24
							Judith Basin								
4	Oats	Disked corn	74.3	20.6	57.1	*	76.9	55.6	86.2	61.7	18.51	5.37	13.14		
	S. wheat	F. plowing	33.3	15.0	23.3	*	24.7	17.6	28.1	23.7	16.59	7.33	9.26		
	Corn	F. plowing	3.3	1.0	3.1	*	2.3	2.2	3.2	2.2	10.00	8.26	1.74	24.14	8.04
							Huntley								
4	Oats	Disked corn					39.3	58.4	81.3	59.7	17.91	5.37	12.54		
	S. wheat	F. plowing					15.0	28.4	28.5	24.0	16.80	7.33	9.47		
	Corn	F. plowing					†23.5	†18.7	†30.4	†24.2	9.68				
							‡1500	‡1690	‡1420	‡1537	3.07	8.26	4.49	26.50	8.83
							Judith Basin								
5	S. wheat	Fallow	38.0	6.8	22.3	*	22.8	21.8	27.0	24.8	17.36	10.94	6.42		
	Oats	F. plowing	67.1	25.0	46.8	*	61.9	50.9	67.8	53.2	15.96	7.08	8.88		
	Fallow		....	....	....		....	....	....	....	....	....	....	15.30	5.10
							Huntley								
5	S. wheat	Fallow					28.8	32.5	50.3	37.2	26.04	10.94	15.10		
	Oats	F. plowing					39.7	49.1	63.2	50.7	15.21	7.08	8.13		
	Fallow						....	....	....	....	....	....	....	23.23	7.74

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre.
*Hailed out. †Grain. ‡Stover.

TABLE XIV (Continued).—Yields, income, cost of production, and profits per acre of the rotations in Group II, comprising three-year rotations containing two of the spring grain crops and either corn or fallow in the third year.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Judith Basin								
6	Barley	..Disked corn	42.7	16.6	29.7	*	34.6	21.6	30.7	29.3	12.01	5.52	6.49		
	Oats	....F. plowing	57.8	19.3	53.7	*	64.4	54.0	65.6	52.4	15.72	7.08	8.64		
	Corn	....F. plowing	5.2	0.9	2.0	*	1.1	1.3	3.3	2.3	9.20	8.26	0.94	16.07	5.37
							Huntley								
6	Barley	..Disked corn					21.6	41.8	67.0	43.5	17.83	5.52	12.31		
	Oats	....F. plowing					34.0	52.8	64.1	50.3	15.09	7.08	8.01		
	Corn	....F. plowing					†18.0	†18.9	†43.5	†26.8	10.72				
							‡1500	‡1740	‡1180	‡1473	2.95	8.26	5.41	25.73	8.58
							Judith Basin								
7	Oats	....S. plowing	74.0	24.0	52.5	*	65.0	60.6	74.6	58.4	17.52	7.08	10.44		
	Barley	..S. plowing	39.1	11.6	**	*	31.7	21.2	34.0	22.9	9.38	7.23	2.15		
	Corn	....S. plowing	4.4	1.1	3.1	*	2.6	2.6	3.2	2.8	11.20	8.26	2.94	15.53	5.18
							Huntley								
7	Oats	....S. plowing					48.1	57.8	87.8	64.6	19.38	7.08	12.30		
	Barley	..S. plowing					24.5	34.6	22.3	27.1	11.11	7.23	3.88		
	Corn	....S. plowing					†33.4	†24.2	†41.8	†33.1	13.24				
							‡1250	‡1710	‡1520	‡1493	2.98	8.26	7.96	24.14	8.05
							Judith Basin								
8	Oats	....Fallow	66.2	20.6	70.0	*	85.3	64.5	85.0	65.3	19.59	10.69	8.90		
	S. wheat	.F. plowing	40.3	8.0	26.1	*	22.3	20.6	33.5	25.1	17.57	7.33	10.24		
	Fallow	..	....	....	....		....	....	....	....	....	....	....	19.14	6.38

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre.
*Hailed out. †Grain. ‡Stover. **No yield.

TABLE XIV (Continued).—Yields, income, cost of production, and profits per acre of the rotations in Group II, comprising three-year rotations containing two of the spring grain crops and either corn or fallow in the third year.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Huntley								
8	Oats	....Fallow					55.3	65.3	96.5	72.9	21.87	10.69	11.18		
	S. wheat	.F. plowing					16.6	27.2	31.3	25.0	17.50	7.33	10.17		
	Fallow	..					....	....	....	....	....	....	....	21.35	7.12
							Judith Basin								
9	Oats	....S. plowing	70.7	22.2	56.5	*	61.2	47.8	75.3	55.0	16.68	7.08	9.60		
	S. wheat	.S. plowing	31.6	10.0	20.8	*	23.5	16.6	29.3	22.0	15.40	7.33	8.07		
	Corn	....S. plowing	4.5	1.6	2.8	*	2.4	2.2	2.4	2.6	10.40	8.26	2.14	19.81	6.60
							Huntley								
9	Oats	....S. plowing					40.6	62.8	86.0	63.1	18.93	7.08	11.85		
	S. wheat	.S. plowing					14.3	24.8	20.8	20.0	14.00	7.33	6.67		
	Corn	....S. plowing					†28.0	†18.6	†34.0	†26.9	10.76				
							‡1500	‡1600	‡1940	‡1680	3.36	8.26	5.86	24.38	8.13
							Judith Basin								
67	Oats	....Disked corn		20.6	53.7	*	86.2	47.8	100.9	61.8	18.54	5.37	13.17		
	S. wheat	.S. plowing		10.0	24.5	*	24.7	19.6	39.6	23.6	16.52	7.33	9.19		
	Corn	....Manured S. plowing		1.3	4.6	*	3.1	2.8	4.0	3.1	12.40	11.46	0.94	23.30	7.77
							Judith Basin								
68	S. wheat	.Disked corn		10.6	18.6	*	30.0	17.0	39.8	23.2	16.24	5.62	10.62		
	Oats	....F. plowing		25.0	62.0	*	66.9	59.0	75.6	57.7	17.31	7.08	10.23		
	Corn	....Manured S. plowing		1.5	3.3	*	2.2	2.5	2.4	2.4	9.60	11.46	-1.86		
							Huntley								
68	S. wheat	.Disked corn					16.5	29.4	44.4	30.1	21.07	5.62	15.45		
	Oats	....F. plowing					35.9	48.2	76.0	53.4	16.02	7.08	8.94		
	Corn	....Manured S. plowing					†26.4	†21.0	†40.0	†29.1	11.64				
							‡2250	‡2280	‡1510	‡2018	4.01	11.46	4.19	28.58	9.53

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover.

is not as profitable a crop at either of the stations as wheat. The corn yields in rotation No. 6 have been light at Judith Basin. Otherwise the differences in yields are not material. The average profits from this rotation are lower at both stations than from rotation No. 1.

Rotation No. 7 is comparable with No. 9 which follows. Both are spring plowed, with barley in No. 7 taking the place of wheat in No. 9. In each case the profit from the barley has been small for a grain crop; however, the corn and oats, especially at Huntley, have shown increased profits over No. 9. At Judith Basin there is an increased profit in favor of No. 9 amounting to $1.42, while at Huntley this increase is only $0.08.

Rotation No. 8 is comparable with No. 4 and No. 9 in that the grain crops are the same, with fallow in No. 8 taking the place of corn in the other two. The profits in each case are in favor of the rotation containing corn. Comparing this rotation with No. 5 where the sequence of the grain crops is reversed, with fallow in both, we find at Judith Basin that the profits from the grain crops favor No. 8, while at Huntley the advantage is with the rotation in which the wheat, rather than the oats, is raised on fallow.

The results of rotation No. 9 may be compared with those of No. 2. The cultural treatment is spring plowing for all crops with the sequence of the oats and wheat changed. The total profits favor No. 2 in each case, but the average differences are not great. In rotation No. 9 oats are grown after corn, and the profits from this crop are greater than they were in rotation No. 2 where they were grown under the same seed-bed preparation but following wheat.

In rotation No. 67 and in rotation No. 4 the oats are grown on disked corn land. The average yield of oats is comparatively high and with the low production cost gives a high profit. Wheat gives a little above the average profit but corn, because of the extra cost of applying the manure, shows a low profit. The average annual acre profit for the rotation is considerably above the average for the group.

The data from rotation No. 68 show that the application of manure does not seem to increase the yield of corn at Judith Basin. The extra cost of its application resulted in growing the crops at a loss; however, the grain crops following have averaged high, especially the oats. At Huntley there seems to have been a stim-

FIG. 4. Annual profits per acre for rotations in Group II. W.=wheat, O.=oats, C.=corn, B.=barley, S. P.=spring plowing, F. P.=fall plowing, D. C.=disked corn land, Fal.=fallow.

ulation of the corn, and especially of the wheat yields on disked corn ground. The profit from this rotation is the highest for this group at Huntley.

In order to summarize and present more clearly the data from Group II, figure 4 has been prepared. The broken-line curve represents the average profits from each rotation at Huntley and the solid line the same thing for Judith Basin. The profits in dollars per acre are shown at the left of the chart. The rotations are represented by their numbers at the top of the chart. The crops, with the tillage used in preparing for each one, are shown at the bottom. For example, rotation No. 1 is the first one shown on the chart. The average profits from this rotation were a little over $9 for Huntley and about $7.70 per acre for Judith Basin. At the bottom of this column, W. D. C., meaning wheat disked on corn land, O. F. P., meaning oats on fall plowing, and C. F. P., meaning corn on fall plowing, show the crop and treatment.

One of the striking facts shown in the chart is the high profit at both stations from rotations in which one small grain crop is seeded on disked corn land. The highest profits in this group are from such rotations at each station, as shown in Nos. 1, 4, and 6 at Huntley. The exceptions are Nos. 6 and 68 at Judith Basin. Both rotations containing barley are low at Judith Basin. At Huntley the least profitable rotations are those containing clean fallow one year in the three. At Judith Basin wheat on fallow is low, but oats on fallow with wheat on fall plowing are only a little below the average. Rotations containing corn, even at Judith Basin where the corn does not mature grain, show an advantage over those containing clean fallow. In the one rotation in which it is applied manure seems to stimulate production at Huntley. At Judith Basin the stimulation is less marked, and the increased yield does not cover the extra cost involved in the application of the manure.

GROUP III

This group contains 3- and 4-year rotations, comparing the effect of peas or rye when turned under as a green manure crop with bare fallow. The 3-year rotations have peas or rye turned under, followed by oats and corn, and are conducted only at Judith Basin.

The 4-year rotations contain peas or rye turned under as a green

manure, or fallow, followed by a small-grain crop, followed by corn, with another small-grain crop on the disked corn land. Those rotations in which both small-grain crops are seeded in the spring are conducted at both places. Those in which one of the small-grain crops is winter wheat and the other is spring seeded, are reported only from Huntley.

The data given in Table XV give the results for Group III.

The two rotations, Nos. 45 and 46, containing rye and peas for green manure do not show a significant difference in yield. The average yield of oats, which immediately follow the green manure and should show any advantage of one over the other, is practically the same. There is a slight difference in corn yield, but it is within the range of normal plat variations. The greater cost of green manuring with peas as compared with rye reduces the profits from the rotation containing peas. This reduction in profit is augmented by the lower corn yield.

The data for rotation No. 14 show that the total income from wheat and oats is about the same for both stations. The cost of production is so increased by green manuring that the final profits are much higher for wheat than for oats.

Rotation No. 15 is similar to No. 14, the difference being the exchange in place of oats and wheat. Oats here, being on disked corn land, are the most profitable crop. The average acre profit is a little less than in rotation No. 14.

The results from rotation No. 16 may be compared with those from No. 14, the only difference being that peas are used for green manure in this rotation in the place of rye in No. 14. The average yields from the grain crops at Judith Basin have been a little heavier from No. 14. At Huntley the differences in yield are not significant. With the lower cost of production when rye is used as a green manure, No. 14 has an advantage in profits at each station.

The results from rotation No. 17 may be compared with No. 15, the only difference being the use of rye as a green manure in the latter, while peas are used in No. 17. The yields of grain at Judith Basin again favor the rotation in which rye is turned under as a green manure. In the comparison of the average yields at Huntley, the differences again are not significant. The profits in each case are higher where rye is used than where peas are used, because of the greater cost of producing peas.

TABLE XV.—Yields, income, cost of production, and profits per acre from rotations in Group III, comprising three- and four-year rotations containing one crop which is plowed under for green manure.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre							Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
			1909	1910	1911	1912	1913	1914	1915						
							Judith Basin								
45	Oats....	Gr. manure	67.7	21.4	54.2	*	75.6	49.0	88.7	59.4	$17.82	$13.56	$4.26		
	Corn....	F plowing	4.8	1.4	3.5	*	2.6	2.3	2.6	2.9	11.60	8.26	3.34		
	Rye.....	Disked corn	....	....	....		....	....	....	....	....	....	....	$7.60	$2.53
46	Oats....	Gr. manure	73.4	22.5	50.5	*	79.4	40.3	88.7	59.0	17.70	16.56	1.14		
	Corn....	F. plowing	4.3	0.8	3.3	*	2.1	2.4	1.8	2.4	9.60	8.26	1.34		
	Peas....	F. plowing	....	....	....		....	....	....	....	....	....	....	2.48	0.83
14	S. wheat	Disked corn	38.6	15.0	21.6	*	28.7	19.5	34.0	26.2	18.34	5.62	12.72		
	Rye.....		....	....	....		....	....	....	....	....	....	....		
	Oats....	Gr. manure	69.6	30.0	59.3	*	76.2	59.6	82.2	62.8	18.84	13.56	5.28		
	Corn....	S. plowing	3.8	1.2	2.4	*	2.1	2.4	2.6	2.4	9.60	8.26	1.34	19.34	4.83
							Huntley								
14	S. wheat	Disked corn					18.8	26.4	40.8	28.7	20.09	5.62	14.47		
	Rye.....						....	....	....	....	....	....	....		
	Oats....	Gr. manure					46.5	62.2	95.2	68.0	20.40	13.56	6.84		
	Corn....	S. plowing					†30.1	†20.6	†37.3	†29.3	11.72				
							‡1300	‡1940	‡1630	‡1623	3.24	8.26	6.70	28.01	7.00
							Judith Basin								
15	Oats....	Disked corn	55.9	20.0	60.6	*	65.9	50.3	80.6	55.5	16.65	5.37	11.28		
	Rye.....		....	....	....		....	....	....	....	....	....	....		
	S. wheat	Gr. manure	3.4	9.0	19.0	*	28.0	15.1	27.8	22.1	15.47	13.81	1.66		
	Corn....	S. plowing	4.2	1.3	2.6	*	1.8	2.5	3.3	2.6	10.40	8.26	2.14	15.08	3.77
							Huntley								
15	Oats....	Disked corn					44.0	63.7	86.9	64.9	19.47	5.37	14.10		
	Rye.....						....	....	....	....	....	....	....		
	S. wheat	Gr. manure					15.0	26.0	43.0	28.0	19.60	13.81	5.79		
	Corn....	S. plowing					†29.2	†21.5	†38.7	†29.8	11.92				
							‡1500	‡1280	‡1600	‡1460	2.92	8.26	6.58	26.47	6.62

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover.

TABLE XV (Continued).—Yields, income, cost of production, and profits per acre from rotations in Group III, comprising three- and four-year rotations containing one crop which is plowed under for green manure.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Judith Basin								
16	S. wheat	Disked corn	32.6	13.7	23.6	*	26.7	19.1	37.6	25 6	17.85	5.62	12.23		
	Peas....		....	....	....		....	....	....	....	....	....	....		
	Oats....	Gr. manure	69.0	19.5	53.9	*	71.2	53.1	83.7	58.4	17.52	16.56	0.96		
	Corn....	S. plowing	4.1	1.2	3.1	*	2.3	2.8	2.4	2.6	10.40	8.26	2.14	15.33	3.83
							Huntley								
16	S. wheat	Disked corn					19.0	26.7	37.3	27.6	19.32	5.62	13.70		
	Peas....						....	....	....	....	....	....	....		
	Oats....	Gr. manure					60.9	56.9	88.8	68.9	20.67	16.56	4.11		
	Corn....	S. plowing					†29.7	†22.8	†38.4	†30.3	12.12				
							‡1200	‡1720	‡1110	‡1343	2.68	8.26	6.54	24.35	6.09
							Judith Basin								
17	Oats....	Disked corn	36.0	26.2	48.4	*	70.3	57.1	76.2	52.4	15.72	5.37	10.35		
	Peas....		....	....	....		....	....	....	....	....	....	....		
	S. wheat	Gr. manure	28.3	11.0	20.5	*	20.5	18.3	31.6	21.7	15.19	16.81	-1.62		
	Corn....	S. plowing	4.5	1.4	3.6	*	2.3	2.0	2.9	2.8	11.20	8.26	2.94	11.29	2.82
							Huntley								
17	Oats....	Disked corn					41.8	61.3	81.9	61.7	18.51	5.37	13.14		
	Peas....						....	....	....	....	....	....	....		
	S. wheat						21.3	26.8	41.6	29.9	20.93	16.81	4.12		
	Corn....	S. plowing					†27.0	†22.8	†36.4	†28.7	11.48				
							‡1950	‡1480	‡1690	‡1706	3.40	8.26	6.62	23.88	5.97

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover.

TABLE XV (Continued).—Yields, income, cost of production, and profits per acre from rotations in Group III, comprising three- and four-year rotations containing one crop which is plowed under for green manure.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Judith Basin								
18	Oats....	Disked corn	51.2	30.0	56.7	*	74.1	63.7	72.5	58.0	17.40	5.37	12.03		
	Fallow..		....	....	....		....	....	....	....	....	....	....		
	S. wheat	Fallow	30.3	8.3	20.6	*	23.1	19.6	33.3	22.5	15.75	10.94	4.81		
	Corn....	S. plowing	4.6	1.2	2.6	*	2.4	1.9	3.5	2.7	10.80	8.26	2.54	19.38	4.85
							Huntley								
18	Oats....	Disked corn					39.3	60.9	87.2	62.5	18.75	5.37	13.38		
	Fallow..						....	....	....	....	....	....	....		
	S. wheat.	Fallow					25.0	27.0	44.8	32.3	22.61	10.94	11.67		
	Corn....	S. plowing					†27.8	†25.3	†41.4	†31.5	12.60				
							‡1200	‡1750	‡1670	‡1540	3.08	8.26	7.42	32.47	8.12
							Judith Basin								
19	S. wheat	Disked corn	29.3	9.7	22.8	*	23.8	18.6	34.1	23.0	16.10	5.62	10.48		
	Fallow..		....	....	....		....	....	....	....	....	....	....		
	Oats....	Fallow	66.5	24.3	53.7	*	65.0	50.0	76.8	56.0	16.80	10.69	6.11		
	Corn....	S. plowing	4.2	1.6	2.8	*	1.9	2.2	2.9	2.6	10.40	8.26	2.14	18.73	4.68
							Huntley								
19	S. wheat	Disked corn					17.5	27.2	40.3	28.3	19.81	5.62	14.19		
	Fallow..						....	....	....	....	....	....	....		
	Oats....	Fallow					62.5	67.2	107.9	79.2	23.76	10.69	13.07		
	Corn....	S. plowing					†31.1	†21.5	†45.2	†32.6	13.04				
							‡1850	‡1990	‡1770	‡1870	3.74	8.26	8.52	35.78	8.94

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover.

TABLE XV (Continued).—Yields, income, cost of production, and profits per acre from rotations in Group III, comprising three- and four-year rotations containing one crop which is plowed under for green manure.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre							Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
			1909	1910	1911	1912	1913	1914	1915						
							Huntley								
53	W.wheat	Disked corn					28.3	32.3	26.6	29.1	20.37	5.62	14.95		
	Rye.....						....	....	....	....	....	....	....		
	Barley..	Gr. manure					19.6	56.6	71.9	49.3	20.21	13.71	6.50		
	Corn....	S. plowing					†30.8	†24.6	†35.2	†30.2	12.08				
							‡1700	‡1740	‡2170	‡1870	3.74	8.26	7.56	28.81	7.20
54	W.wheat	Disked corn					27.0	30.8	27.5	28.4	19.88	5.62	14.26		
	Peas....						....	....	....	....	....	....	....		
	Barley..	Gr. manure					36.3	63.6	60.0	53.3	21.85	16.71	5.14		
	Corn....	S. plowing					†30.1	†24.6	†41.0	†31.9	12.76				
							‡1750	‡1560	‡2110	‡1806	3.60	8.26	8.10	27.50	6.87
51	Barley..	Disked corn					23.1	44.0	63.9	43.7	17.91	5.52	12.39		
	Rye.....						....	....	....	....	....	....	....		
	W.wheat	Gr. manure					22.6	35.5	36.6	31.6	22.12	13.81	8.31		
	Corn....	S. plowing					†33.2	†22.8	†36.8	†30.9	12.36				
							‡1500	‡1500	‡1910	‡1636	3.26	8.26	7.36	28.06	7.01
92	Barley..	Disked corn					21.0	48.3	61.3	43.5	17.85	5.52	12.33		
	Peas....						....	....	....	....	....	....	....		
	W.wheat	Gr. manure					31.3	33.6	40.8	35.2	24.64	16.81	7.83		
	Corn....	S. plowing					†30.1	†26.4	†36.6	†31.0	12.40	8.26	8.10	28.26	7.06
57	Barley.	Disked corn					27.0	48.7	66.4	47.3	19.39	5.52	13.87		
	Fallow.						....	....	....	....	....	....*	....		
	W.wheat	Fallow					35.1	39.2	58.5	44.3	31.01	10.94	20.07		
	Corn...	S. plowing					†30.8	†21.0	†34.4	†28.7	11.48				
							‡2500	‡1560	‡1640	‡1900	3.80	8.26	7.02	40.96	10.24

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover.

TABLE XV (Continued).—Yields, income, cost of production, and profits per acre from rotations in Group III, comprising three- and four-year rotations containing one crop which is plowed under for green manure.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Huntley								
114	W.wheat	Disked corn					28.3	32.7	25.6	28.9	20.23	5.62	14.61		
	Rye....						....	....	....	....	....	....	....		
	Oats....	Gr. manure					45.9	65.5	99.0	70.1	21.03	13.56	7.47		
	Corn....	S. plowing					†27.8	†24.7	†38.8	†30.4	12.16				
							‡1750	‡1710	‡2130	‡1863	3.77	8.26	7.62	29.70	7.42
116	W.wheat	Disked corn					26.1	30.1	27.8	27.9	19.53	5.62	13.91		
	Peas....						....	....	....	....	....	....	....		
	Oats....	Gr. manure					68.1	62.5	90.6	73.7	22.11	16.56	5.55		
	Corn....	S. plowing					†29.1	†24.5	†35.8	†29.8	11.92				
							‡1900	‡1670	‡2450	‡2007	4.00	8.26	7.66	27.12	6.78
115	Oats....	Disked corn					49.0	60.3	93.8	67.7	20.31	5.37	14.94		
	Rye.....						....	....	....	....	....	....	....		
	W.wheat	Gr. manure					23.0	37.1	38.3	32.8	22.96	13.81	9.15		
	Corn....	S. plowing					†34.8	†24.2	†33.7	†30.9	12.36				
							‡2100	‡1750	‡2170	‡2007	3.00	8.26	8.10	32.19	8.05
117	Oats....	Disked corn					41.5	65.3	82.7	63.2	18.96	5.37	13.59		
	Peas....						....	....	....	....	....	....	....		
	W.wheat	Gr. manure					42.5	33.3	36.6	32.5	26.25	16.81	9.44		
	Corn....	S. plowing					†35.8	†24.0	†33.7	†31.2	12.48				
							‡2450	‡1670	‡1900	‡2007	4.00	8.26	8.22	31.25	7 81
118	Oats....	Disked corn					50.0	67.2	94.4	70.5	21.15	5.37	15.78		
	Fallow..						....	....	....	....	....	....	....		
	W.wheat.	Fallow					48.1	36.6	56.8	42.2	33.04	10.94	22.10		
	Corn....	S. plowing					†34.2	†27.6	†34.4	†32.1	12.84				
							‡2950	‡2020	‡1750	‡2240	4.80	8.26	9.06	46.94	11.73

Corn fodder at Judith Basin in tons per acre. Corn stover at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover.

The results from rotation No. 18, containing fallow, may be directly compared with those from No. 15 where rye is used as a green manure and No. 17 where peas are used in the same way. Otherwise, these rotations are the same. At Judith Basin there is a difference of less than a bushel in the average yield of wheat, which is the first crop after the fallow. The oat yields are lowest in No. 17 and highest in No. 18. At Huntley the yields of wheat after fallow are higher than after either method of green manuring. The corn and oat yields are higher where rye has been used as a green manure.

The results from rotation No. 19, containing fallow, may be directly compared with those from No. 14, containing rye as a green manure, and with those from No. 16, containing peas as a green manure. At Judith Basin the oats, which are the first crop after different fallow methods, show the lowest yield after bare fallow and the highest after rye turned under. The wheat yields show the same relation. The profits are highest from No. 14 and lowest from No. 16. The yields of oats at Huntley are the most significant, being highest after fallow and lowest after peas. The profits are highest from No. 19 and lowest from No. 16.

The data from rotations Nos. 53 and 54 offer a direct comparison of rye and peas as green manuring crops in preparation for barley. Two years out of three and in the average yield, peas have been better than rye as a green manure crop. The increase in yield, however, has not been sufficient to overcome the greater cost of using peas, and the profit from the barley is less after peas than after rye. The average profit per acre favors the rotation containing rye.

The crops that are harvested in rotations Nos. 51, 92, and 57 are the same with the same sequence, the difference being only in the preparation for the winter wheat, rye being used for green manure in No. 51, peas in No. 92, and bare fallow in No. 57. The yields of winter wheat and barley have been constantly high in No. 57 with the yields of corn slightly low. Winter wheat on fallow has shown exceptionally good yields, and with the lower cost of production as compared with the green manure crops, the profits from winter wheat in No. 57 have a decided advantage. As between Nos. 92 and 57, there is only a difference of $0.05, while No. 57 shows an increase of over $3 over the other methods.

The data for rotations Nos. 114 and 116 offer a direct com-

parison of rye and peas as a green manure crop in preparation for oats. Two years out of the three the yield of oats was higher after rye. The other year the difference in favor of peas was high enough to make the average favor peas. The profits, however, have been almost $2 less where peas were used than where rye was used. The average profit from the rotations is higher for the one containing rye.

The three rotations, Nos. 115, 117 and 118, are compared as preparations for winter wheat. Rye is used as a green manure in No. 115, peas in No. 117, and bare fallow is the preparation in No. 118. The three crops that are harvested are all the same and in the same order. The yields and profits from all crops have been highest in No. 118. As between Nos. 115 and 117, the yield of winter wheat is 5 bushels higher after peas, with a small increase in profit. This increase in yield in No. 117 is mostly due to the large increase in 1913. The last two years the yields have been in favor of rotation No. 115. In annual profits No. 115 shows a small increase over No. 117.

In figure 5 are shown graphically the profits from each rotation in Group III. The broken-line curve represents the average profits from each of these rotations at Huntley and the solid-line curve the same thing for Judith Basin. The rotations are represented by their numbers along the top of the chart. The crops and the tillage used in preparation for them are shown for each rotation at the bottom of the column. Profits are in dollars per acre as shown at the left of the chart. At Huntley the rotations showing the greatest profit are those containing clean fallow in place of a green manure crop. The profits at Judith Basin are not as large as at Huntley, but with the exception of rye as a green manure crop in preparation for oats, the two rotations containing clean fallow show the highest. The lowest profit at Judith Basin is where a green manure crop enters into a 3-year rotation. In such a rotation the heavy cost of this practice has to be borne by only two harvested crops, while in a 4-year rotation it can be divided between three harvested crops. The yields following green manuring haave not been commensurate with the expense involved at either station. The chart indicates that with the present state of fertility bare fallow is a more profitable practice than green manuring. These soils are still rich in virgin fertility and the problem of production is moisture supply rather than fertility.

FIG. 5. Annual profits per acre for rotations in Group III. W.=wheat, O.=oats, C.=corn, W. W.=winter wheat, R.=rye, P.=peas, S. P.=spring plowing, F. P.=fall plowing, G. M.=green manure, Fal.=fallow, D. C.=disked corn land.

GROUP IV

In Group IV are brought together those rotations containing sod crops. The sod crops used have been brome grass, alfalfa, and red clover. Each of these crops is used in combination with oats, corn, and spring wheat in the same sequence and under the same treatment, in order to measure the effect of the different sod crops.

In Table XVI are given the data for Group IV.

Rotations Nos. 10 and 11 afford a direct comparison between brome grass and its effect as a sod crop in No. 10 and clover and its effect as a sod crop in No. 11. The brome grass is seeded with the wheat in rotation No. 10, while it is necessary to plow the

wheat stubble in rotation No. 11 as a seed-bed preparation for the clover, thus increasing the cost of production. Brome grass is well adapted to conditions at Judith Basin, with the result that there is much difficulty in eradicating it from the crops which follow. For this reason the yields in rotation No. 10 have been light. In 1913 and 1914 the wheat in this rotation was so badly damaged that a failure was reported. The profits from clover in No. 11 have been much less than from brome grass in No. 10. However, the increased profit from the wheat in No. 11 over that in No. 10 has almost made up for this, there being but $0.58 greater profit from No. 10 than from No. 11.

Rotation No. 12 is the same as No. 10 except that flax is added and used as a sod crop. The results show that the flax has been produced at a loss of $1.71. The brome grass seems to have caused equally as much trouble with as much decrease in yields in No. 12 as in No. 10. The latter rotation shows an increase in profits over rotation No. 12 of $0.65.

Rotation No. 41 is the same as No. 10, except that brome grass runs three years and makes it a year longer. At Huntley the brome was grown at a loss, but the other crops gave yields sufficiently high to more than overcome this loss and the rotation shows a profit. At Judith Basin brome was profitable but so hard to kill out that the oats following it just paid the production cost. The rotation as a whole shows an acre profit of about one dollar less than at Huntley.

Rotation No. 42 is similar to No. 41 but has alfalfa instead of brome grass. At neither station has the alfalfa produced enough hay the first year to pay production cost. At Judith Basin the alfalfa also shows a loss the third year when it is plowed in the fall. The grain crops have given higher yields at this station in this rotation than they did following brome grass. The alfalfa, however, was less profitable than brome and the final acre profit from this rotation is less than from the one containing brome. At Huntley the average profit from this rotation is only a little less than where brome was used.

In figure 6 are shown graphically the average profits from each rotation in Group IV. The profits are indicated in dollars per acre as shown at the left of the chart. The rotations are represented

TABLE XVI.—Yields, income, cost of production, and profits per acre from rotations in Group IV, comprising five- and six-year rotations comparing different sod crops and their effect on the following crops.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Judith Basin								
10	S. wheat.	Disked corn	36.8	11.0	21.3	*	**	**	32.3	16.9	$11.83	$5.62	$6.21		
	Brome...		0.75	**	0.5	2.6	1.2	2.1	1.8	1.3	10.40	3.60	6.80		
	Brome...		1.6	**	**	0.7	1.0	1.6	0.8	0.8	6.40	3.60	2.80		
	Oats.....	Brome sod	62.5	13.7	21.8	*	38.7	26.2	74.3	39.5	11.85	9.13	2.72		
	Corn.....	S. plowing	3.7	1.2	1.9	*	0.8	1.7	3.1	2.1	8.40	8.26	0.14	$18.67	$3.73
11	S. wheat.	Disked corn	35.6	7.7	27.6	*	19.2	22.8	32.3	24.2	16.94	5.62	11.32		
	Clover...	F. plowing	....	**	0.5	*	1.5	....	1.5	0.5	4.00	8.80	-4.80		
	Clover...		1.8	**	....	0.7	....	1.5	....	0.6	4.80	3.60	1.20		
	Oats.....	Clover sod	72.5	22.8	37.8	*	50.3	50.6	74.3	51.4	15.42	9.13	6.29		
	Corn.....	S. plowing	3.7	1.0	3.2	*	2.3	1.8	3.1	2.5	10.00	8.26	1.74	15.75	3.15
12	S. wheat.	Disked corn	31.0	9.5	24.0	*	**	**	27.0	15.3	10.71	5.62	5.09		
	Brome....		0.5	**	1.1	0.8	0.7	2.1	**	0.7	5.60	3.60	2.00		
	Brome....	Meadow	2.9	**	**	2.5	0.5	1.3	0.7	1.1	8.80	3.60	5.20		
	Flax.....	Brome sod	9.2	**	8.5	*	3.8	8.0	8.7	6.4	7.04	8.75	-1.71		
	Oats.....	F. plowing	63.7	19.5	45.7	*	33.7	46.2	50.6	43.2	12.96	7.08	5.88		
	Corn.....	S. plowing	5.1	1.6	2.6	*	1.8	1.6	2.7	2.6	10.40	8.26	2.14	18.60	3.10
41	Wheat...	Disked corn	31.3	7.0	23.5	*	**	9.6	31.4	17.2	12.04	5.62	6.42		
	Brome....		1.6	0.8	0.5	0.9	0.7	1.9	1.6	1.1	8.80	3.60	5.20		
	Brome....		2.0	0.7	1.3	1.7		2.2	0.7	1.2	9.60	3.60	6.00		
	Brome....		1.5	0.7			1.7	1.2	0.75	0.8	6.40	3.60	2.80		
	Oats.....	F. plowing	62.5	21.8	23.2	*	38.4	16.8	25.6	31.4	9.42	9.13	0.29		
	Corn.....	S. plowing	4.3	1.5	2.2	*	1.1	2.1	2.9	2.4	8.32	8.26	0.06	20.77	3.44

Corn, brome, clover, and alfalfa yields at Judith Basin in tons per acre. Corn stover and alfalfa at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover. **Failure.

TABLE XVI (Continued).—Yields, income, cost of production, and profits per acre from rotations in Group IV, comprising five- and six-year rotations comparing different sod crops and their effect on the following crops.

Rotation number	Crop	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per crop per acre	Cost of production per crop per acre	Profit or loss per crop per acre	Profit per rotation	Average profit or loss per acre per rotation
							Huntley								
41	Wheat...	Disked corn					20.3	26.5	39.6	28.8	20.16	5.62	14.54		
	Brome....						1100	1300		800	3.20	3.60	-0.40		
	Brome....						1180	1400		860	3.44	3.60	-0.16		
	Brome....						1150	1350		833	3.33	3.60	-0.27		
	Oats.....	Backset					51.9	43.7	59.4	51.6	15.48	9.13	6.35		
	Corn.....	S. plowing					†30.7	†17.9	†36.0	†28.2	11.28				
							‡1300	‡2020	‡2620	‡1980	3.96	8.26	6.98	27.04	4.51
							Judith Basin								
42	Wheat...	Disked corn	38.6	10.3	23.3	*	10.3	19.6	32.0	22.4	15.68	5.62	10.06		
	Alfalfa...	F. plowing		**	1.1	*	1.9	1.7	1.2	0.8	6.40	8.80	-2.40		
	Alfalfa...		1.9	**	1.2	1.3	1.8	1.7	1.1	1.3	10.40	4.10	6.30		
	Alfalfa...		1.9	**		1.1				0.4	3.20	4.10	-0.90		
	Oats.....	Alfalfa sod	56.8	14.3	33.1	*	30.6	47.1	41.8	37.3	11.19	9.13	2.06		
	Corn.....	S. plowing	4.5	1.3	2.4	*	1.9	2.0	3.2	2.5	10.00	8.26	1.74	16.86	2.81
							Huntley								
42	Wheat...	Disked corn					15.8	27.9	36.0	26.6	18.62	5.62	13.00		
	Alfalfa...						610			203	0.80	8.80	-8.00		
	Alfalfa...						1110	2400	2180	1893	7.56	4.10	3.46		
	Alfalfa...						1120	2350	2060	1843	7.36	4.10	3.26		
	Oats.....	Backset					46.9	51.9	72.8	58.7	17.61	9.13	8.48		
	Corn.....	S. plowing					†22.1	†16.8	†35.0	†24.6	9.84				
							‡800	‡1960	‡2640	‡1800	3.60	8.26	5.18	25.38	4.23

Corn, brome, clover, and alfalfa yields at Judith Basin in tons per acre. Corn stover and alfalfa at Huntley in pounds per acre. *Hailed out. †Grain. ‡Stover. **Failure.

by their numbers at the top of the chart. Crops and the treatment in preparation for each are shown at the bottom. This group shows less profit than any other. The indications are that the production of hay crops is not adapted to short rotations in these sections. Rotations containing brome grass have been more profitable than those containing alfalfa.

FIG. 6. Annual profits per acre for rotations in Group IV. O.=oats, C.=corn, W.=wheat, Br.=brome grass, Cl.=clover, Alf.=alfalfa, B. S.=back setting, S. P.=spring plowing, D. C.=disked corn land, F. P.=fall plowing.

TABLE XVII.—Profits from each rotation in each group.

Station	Group I. Two-year rotations	Profits per acre	Group II. Three-year rotations	Profits per acre	Group III. Three- and four-year rotations	Profits per acre	Group IV. Five- and six-year rotations	Profits per acre
Judith Basin..	Wheat Corn	$6.89	Wheat Oats Corn	$7.65	Oats Wheat Corn	$7.77	Wheat Brome Brome Oats Corn	$3.73
Huntley		9.05		9.05				
Judith Basin..	Wheat Fallow	2.37	Wheat Oats Corn	6.86	Wheat Oats Corn	6.33	Wheat Clover Clover Oats Corn	3.15
Huntley		3.70		8.50		9.53		
Judith Basin..	Corn Oats	8.03	Wheat Oats Corn	6.78	Oats Corn Rye	2.53	Wheat Brome Brome Flax Oats Corn	3.10
Huntley		9.08		8.24				
Judith Basin..	Oats Fallow	4.50	Oats Wheat Corn	8.04	Oats Corn Peas	0.83	Wheat Brome Brome Brome Oats Corn	3.44
Huntley		4.99		8.83				4.51
Judith Basin..			Wheat Oats Fallow	5.10	Wheat Rye Oats Corn	4.83	Wheat Alfalfa Alfalfa Alfalfa Oats Corn	2.81
Huntley				7.74		7.00		4.23
Judith Basin..			Barley Oats Corn	5.37	Oats Rye Wheat Corn	3.77		
Huntley				8.58		6.62		
Judith Basin..			Oats Barley Corn	5.18	Wheat Peas Oats Corn	3.83		
Huntley				8.05		6.09		
Judith Basin..			Oats Wheat Fallow	6.38	Oats Peas Wheat Corn	2.82		
Huntley				7.12		5.97		
Judith Basin..			Oats Wheat Corn	6.60	Oats Fallow Wheat Corn	4.85		
Huntley				8.13		8.12		
Judith Basin..					Wheat Fallow Oats Corn	4.68		
Huntley						8.94		

SUMMARY FOR CROP ROTATIONS

In Table XVII are brought together various rotations representing a number of crop groupings, and the profit from each is given for both stations where the rotation has been tried at both. This table indicates the relative profitableness of the various groups of crops at each station.

In the 2-year rotations with spring grains and corn and spring grains and fallow, the rotations containing corn show an advantage even at Judith Basin where the corn does not mature grain.

In the 3-year rotations containing spring grains for two years followed by a cultivated crop, corn is a profitable substitute for summer fallow. In these rotations the systems containing a grain crop seeded on disked corn are the most profitable.

Rye is more profitable as a green manure crop than are peas when used in 3- and 4-year rotations.

Three-year rotations containing one crop turned under for green manure followed by grain and corn have not been as profitable as the 4-year systems in which another grain crop is added.

Four-year rotations containing fallow for one year show more profit than 4-year rotations containing one year of green manure.

Profits are comparatively low on rotations containing sod crops for two or three years.

Rotations with brome grass as a sod crop were more profitable than those with alfalfa as a sod crop.

CONTINUOUS CROPPING

In order to determine the effect of growing the same crop continuously on the land, there is carried on at each station what is known as the continuous cropping series. In this series each plat has different treatment from the other plats in the series, but each plat has the same treatment from year to year and is cropped to the same crop. The exceptions to this are plats C and D in each series, which are alternately in crop and summer fallow. That is, in any series either the C or D plat will be cropped one year and the other plat fallowed. The following year the fallowed plat will be cropped and the other plat fallowed. The crops included in the continuous cropping series are winter wheat, spring wheat, oats, corn, and flax at both stations and barley at Judith Basin.

The different plats are treated in the following manner. Plat A

is spring plowed to a depth of about four inches in all series except for winter wheat, when it is plowed to the same depth just before seeding. After plowing, only the minimum amount of cultivation necessary to prepare a seed-bed is given.

Plat B is always fall plowed. The plowing is done to a depth of 7 or 8 inches as soon as practicable after the previous crop has been taken off.

Plats C and D alternate summer fallowing and cropping.

Plat E is fall plowed at the same time and to the same depth as plat B. At the time of plowing a subsoiler is run in the bottom of the furrow, loosening the soil to a greater depth. At Judith Basin it has been possible to subsoil only about 3 inches below the bottom of the furrow, while at Huntley a total depth of 14 inches or more is reached.

Plat F is listed at the same time that plat B is plowed. For winter wheat it is worked level just before seeding and for the other crops it is left ridged through the winter.

At Judith Basin there are two extra plats—plat G in spring wheat and plat G in corn. In the spring wheat series plat G is spring plowed, but plowed 7 or 8 inches deep. Plat G in corn is spring listed.

The treatments described apply to their respective plats in all series of the continuous cropping experiments.

In Table XVIII the data from the continuous cropping series at Judith Basin are brought together.

In the winter wheat series the continuously cropped, fall plowed plats have been the most profitable. It seems to make no practical difference whether the soil is plowed 3 or 4 inches deep as in plat A, or 7 or 8 inches as in plat B. The yields following subsoiling and listing have both been lower than where the land was plowed with an ordinary plow. There seems to be no necessity for subsoiling at this station. Listing gave the lowest yield in the continuously cropped series, but the lowest profit per acre was from fallow. When the yield is divided by two, as is necessary in an alternate cropping series, the increase has not been sufficient to pay for the extra labor involved.

In the spring wheat series the listed plat has given the highest profit per acre. The yield was a little less than that obtained from

TABLE XVIII.—Yields, income, cost of production, and profits per acre from various methods of continuous cropping and alternate cropping and summer fallowing, for winter wheat, spring wheat, oats, corn, flax, and barley at Judith Basin.

Plat	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per acre	Cost of production per acre	Profit or loss per acre
					Winter Wheat							
A	Fall plowing	56.5	23.8	22.0	13.2	25.5	16.3	25.0	26.0	$18.20	$6.92	$11.28
B	Fall plowing	60.3	24.0	23.5	12.1	23.2	16.3	28.5	26.8	18.76	7.33	11.43
C	Fallow	55.6	*	31.6	*	31.8	*	51.5				
D	Fallow	*	22.0	*	17.5	*	25.5	*	‡16.8	11.76	5.47	6.29
E	Fall plowing and subsoiling	31.0	23.2	22.4	12.5	26.2	15.5	28.3	22.7	15.89	8.76	7.13
F	Listing	32.0	21.7	22.3	10.8	24.3	20.1	21.1	21.7	15.19	6.22	8.97
					Spring Wheat							
A	Spring plowing	33.8	10.7	22.1		23.5	16.1	28.6	22.4	15.68	6.92	8.76
B	Fall plowing	33.4	14.0	22.0		18.5	15.8	27.0	21.7	15.19	7.33	7.86
C	Fallow	*	6.4	*		*	18.3	*				
D	Fallow	34.0	*	19.1		22.3	*	34.6	‡11.2	7.84	5.47	2.37
E	Fall plowing and subsoiling	36.3	15.0	23.5		22.8	16.5	25.5	23.3	16.31	8.76	7.55
F	Listing	33.3	8.3	26.5		23.3	17.1	27.6	22.7	15.89	6.22	9.67
					Oats							
A	Spring plowing	75.3	24.3	52.0		64.1	44.6	54.0	52.4	15.72	6.67	9.05
B	Fall plowing	66.2	20.9	51.5		65.0	49.3	50.6	50.6	15.18	7.08	8.10
C	Fallow	*	25.8	*		*	61.5	*				
D	Fallow	78.7	*	65.9		78.4	*	82.8	‡32.8	9.84	5.34	4.50
E	Fall plowing and subsoiling	63.7	25.3	53.0		65.0	40.6	57.1	50.8	15.24	8.51	6.73
F	Listing	72.5	22.8	53.5		63.4	37.5	56.2	51.0	15.30	5.97	9.33

*Fallow. ‡The average yields from summer tillage have been divided by two to get average annual yields, and one-half of the total cost of producing a crop has been charged so as to make the profit shown comparable with that from continuous cropping.

TABLE XVIII (Continued).—Yields, income, cost of production, and profits per acre from various methods of continuous cropping and alternate cropping and summer fallowing, for winter wheat, spring wheat, oats, corn, flax, and barley at **Judith Basin.**

Plat	Method of soil preparation	Yield in bushels per acre 1909	1910	1911	1912	1913	1914	1915	Average yield in bushels per acre	Income per acre	Cost of production per acre	Profit or loss per acre
	Corn†											
A	Spring plowing	5.0	1.3	3.6		2.5	2.4	3.8	3.1	12.40	7.85	4.55
B	Fall plowing	5.5	1.5	3.5		2.0	1.8	4.2	3.1	12.40	8.26	4.14
C	Fallow	*	1.6	*		*	1.7	*				
D	Fallow	5.8	*	2.0		3.1	*	3.3	‡1.5	6.00	5.93	0.07
E	Fall plowing and subsoiling	5.7	1.8	2.4		2.9	2.5	4.0	3.2	12.80	9.69	3.11
F	Listing	3.9	1.4			2.3	1.8	3.3	2.1	8.40	5.23	3.17
	Flax											
A	Fall plowing	16.9	5.3	14.6		14.2	11.4	19.4	13.6	14.96	6.29	8.67
B	Fall plowing	14.1	6.2	13.2		12.9	9.1	16.0	11.9	13.09	6.70	6.39
C	Fallow	*	5.8	*		*	8.3	*				
D	Fallow	17.6	*	15.5		16.4		20.1	‡7.0	7.70	5.15	2.55
E	Fall plowing and subsoiling	15.0	6.5	14.1		13.2	10.7	17.5	12.8	14.08	8.13	5.95
F	Listing	15.8	5.5	10.5		12.3	12.3	20.1	12.7	13.97	5.59	7.38
	Barley											
A	Spring plowing	45.2	10.0	23.9		21.9	11.6	27.5	23.4	9.59	6.82	2.77
B	Fall plowing	43.3	12.5	24.1		21.9	18.1	24.0	23.9	9.79	7.23	2.56
C	Fallow	*	15.8	*		*	25.8	*				
D	Fallow	49.4	*	27.5		32.7	*	37.1	‡15.7	6.43	5.42	1.01
E	Fall plowing and subsoiling	48.3	15.0	32.6		32.9	23.5	25.8	29.7	12.17	8.66	3.51
F	Listing	47.9	12.5	30.4		32.5	21.8	26.5	28.6	11.72	6.12	5.60

*Fallow. †Corn fodder in tons per acre. ‡The average yields from summer tillage have been divided by two to get average annual yields, and one-half of the total cost of producing a crop has been charged so as to make the profit shown comparable with that from continuous cropping.

subsoiling but the cost was also less. Between fall and spring plowing the advantage is in favor of the latter method. Summer fallow is again the least profitable practice.

In the oat series the ranking is the same as for spring wheat, listing being the most profitable and summer fallow the least profitable practice. The shallow spring plowing gave a profit almost $1 greater than fall plowing.

In the corn series spring plowing has been the most profitable and fall plowing next. The yields on the summer fallowed land have been sufficient only to pay the cost of production. There is no material difference between listing and subsoiling, both averaging about a dollar less in profit than ordinary plowing.

In the flax series shallow spring plowing has been the most profitable and listing second. Subsoiling at the time of fall plowing increased the yield about one bushel per acre but decreased the profits. Summer fallow gave the lowest annual profit.

In the barley series there is very little difference between spring and fall plowing. Both listing and subsoiling in this series show higher yields and profits than ordinary plowing. This apparent difference due to tillage methods is not warranted. On account of a certain location of the spring and fall plowed plats they were extensively damaged several years by gophers. Summer fallow gave the lowest average yield and profit.

In Table XIX the data from the continuous cropping series at Huntley are given.

In the winter wheat series the difference in average yields is not more than two bushels. The highest yield has been obtained from summer fallow and this has also proved the most profitable practice. Even when the average yield is divided by two, the profit is $3.49 higher than from the most profitable method of continuous cropping. Fall plowing is second in profitableness and listing third, while subsoiling has been the least profitable.

In the spring wheat series the average annual yield has been highest from listing. It has also been the most profitable method. Spring and fall plowing have given practically the same yields but the former has been slightly more profitable. This is due partially to a lesser production cost and partially to a slight increase in yields. Subsoiling gave about the average yield but because of

TABLE XIX.—Yields, income, cost of production, and profits per acre from various methods of continuous cropping and alternate cropping and summer fallowing, for winter wheat, spring wheat, oats, corn, and flax at **Huntley**.

Plat	Method of soil preparation	Yields in bushels per acre 1913	1914	1915	Average yield in bushels per acre	Income per acre	Cost of production per acre	Profits per acre
			Winter Wheat					
A	Fall plowing		30.8	12.3	21.5	$15.05	$6.92	$8.13
B	Fall plowing		25.7	13.3	19.5	13.65	7.33	6.32
C	Fallow		46.1	*				
D	Fallow		*	51.6	‡24.4	17.08	5.47	11.61
E	Fall plowing and subsoiling		27.8	13.6	20.7	14.49	8.76	5.75
F	Listing		26.7	13.1	19.6	13.72	6.22	7.50
			Spring Wheat					
A	Spring plowing	16.0	18.3	24.5	19.6	13.72	6.92	6.80
B	Fall plowing	11.8	20.2	25.3	19.1	13.37	7.33	6.04
C	Fallow	*	19.5	*				
D	Fallow	22.8	*	36.5	‡13.1	9.17	5.47	3.70
E	Fall plowing and subsoiling	14.5	17.5	25.5	19.2	13.44	8.76	4.68
F	Listing	16.5	19.5	27.3	21.1	14.77	6.92	7.85
			Oats					
A	Spring plowing	35.3	50.6	58.4	48.1	14.43	6.67	7.76
B	Fall plowing	34.0	48.4	56.9	46.4	13.92	7.08	6.84
C	Fallow	*	40.3	*				
D	Fallow	64.6	*	101.9	‡34.4	10.33	5.34	4.99
E	Fall plowing and subsoiling	39.3	52.8	61.9	51.3	15.39	8.51	6.88
F	Listing	45.6	48.7	63.4	52.6	15.78	5.97	9.81
			Corn**					
A	Spring plowing	†24.4	†19.2	†36.3	†26.6			
		‡1250	‡1500	‡1760	‡1503	13.65	7.85	5.79
B	Fall plowing	†14.8	†13.2	†40.6	†22.8			
		‡1400	‡1360	‡1470	‡1410	11.94	8.26	3.68
C	Fallow	*	†25.0	*				
		*	‡1490	*	†16.3			
D	Fallow	†27.2	*	†45.2	‡9.40	8.38	5.94	2.54
		‡1900	*	‡2250				
E	Fall plowing and subsoiling	†25.7	†13.9	†42.5	†27.4			
		‡2300	‡1590	‡1450	‡1780	14.52	9.69	4.83
F	Spring listing	†30.1	†22.5	†40.7	†31.1			
		‡1300	‡1910	‡1830	‡1680	15.80	5.23	10.37
			Flax					
A	Spring plowing	12.5	7.8	14.6	11.6	12.76	6.29	6.47
B	Fall plowing	12.5	8.4	16.7	12.5	13.75	6.70	7.05
C	Fallow	*	8.9	*				
D	Fallow	16.0	*	23.6	§8.1	8.91	5.15	3.76
E	Fall plowing and subsoiling	11.9	4.7	13.4	10.0	11.00	8.13	2.87
F	Listing	8.9	6.2	17.0	10.7	11.77	5.59	6.18

*Fallow. **Stover in pounds per acre. †Grain. ‡Stover. §The average yields from summer tillage have been divided by two to get the average annual yields, and one-half of the total cost of producing a crop by summer tillage has been charged so as to make the profit shown comparable with that from continuous cropping.

its greater production cost was less profitable than the other methods of continuous cropping. The yields of spring wheat on fallow have not been sufficiently high to justify this practice.

In the oat series the highest yield and greatest profit have been from listing. Subsoiling is next in order of yields, but because of greater cost is lower in profits per acre. Spring plowing gave greater yields and greater profit per acre than fall plowing. Summer fallow, though giving the highest yields, has been the least profitable practice.

In the corn series listing has been decidedly the most profitable practice. The yields from this method were high and the cost comparatively low. Spring plowing has been considerably better than fall plowing in both yields and profit. It ranks next to listing in point of profit. Fall plowing has been the least profitable of all the methods under continuous cropping. Summer fallow has given the lowest profit of all.

In the flax series the highest yields and the highest profit have been from fall plowing, with spring plowing second. Subsoiling has been the least profitable practice. Summer fallow, though giving consistently high yields, has not been as profitable as any of the methods of continuous cropping except subsoiling.

SUMMARY

1. The average annual precipitation for the past eighteen years at Judith Basin has been 16.66 inches. Of this amount an average of 10.90 inches has fallen between April 1st and September 30th. The average annual precipitation at Huntley for the past nine years has been 13.74 inches, an average of 8.42 inches falling between April 1st and September 30th. At both stations May and June are the months of highest average rainfall.

2. The total evaporation for the months of April to August, inclusive, has averaged 25.049 inches at Judith Basin for the past eight years. Huntley for the same months has an average for the past four years of 20.397 inches.

3. The average mean temperature for the months of April to September, inclusive, is 54.8 degrees at Judith Basin and 59.7 degrees at Huntley. The greatest difference between the mean monthly temperature of the two stations is in June when Huntley has the highest temperature.

4. In the two-year rotations, spring grains and corn and spring grains and fallow, the systems containing corn show the highest profit.

5. In three-year rotations containing spring grains for two years and either corn or fallow in the third year, those rotations containing corn have been more profitable than those containing fallow.

6. In the three-year rotations containing two years of small grain and one year of corn, it has been found more profitable to disk the corn land than to plow it as a preparation for one of the small grain crops.

7. In the rotations containing one crop turned under for green manure, rye has been more profitable than peas as a green manure crop.

8. Three-year rotations containing a green manure crop have been less profitable than four-year rotations containing a green manure crop.

9. Either three- or four-year rotations containing a green manure crop have been less profitable than similar rotations where clean fallow replaced the green manuring.

10. Rotations containing sod crops for two or three years have given comparatively low profits. Brome grass has been a little more profitable than alfalfa as a sod crop.

11. In the winter wheat series of continuous cropping experiments, fall plowing was the most profitable practice at Judith Basin. Summer fallowing has shown the least profit. At Huntley the most profitable method for winter wheat was summer fallowing, subsoiling being the least profitable.

12. In the spring wheat series listing has been the most profitable and sumer fallowing the least profitable method at Judith Basin. At Huntley listing was the most profitable.

13. In the oat series at Judith Basin listing has been the most profitable and summer fallow the least profitable practice. Listing was most profitable at Huntley.

14. At Judith Basin corn on spring plowing was most profitable and on summer fallow the least profitable. At Huntley corn on spring listing was the most profitable and on summer fallow the least profitable.

15. At Judith Basin spring plowing has been most profitable in

the flax series and summer fallow the least profitable. At Huntley flax on fall plowing has been most profitable and on subsoiling least profitable.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION
BOZEMAN, MONTANA

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Studies on the Composition and Nutritive Value of Clover Hay and Clover Silage in Montana

BY
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Chemist

The work reported in this bulletin was planned by the head of the chemistry department, Professor Edmund Burke. A large proportion of the analyses was made by George Ennis Smith, assistant chemist, who recently resigned from the Montana Experiment Station staff. The final analyses were made, the results compiled, and the bulletin written by Morris J. Blish, assistant chemist.

F. B. Linfield,
Director

Studies on the Composition and Nutritive Value of Clover Hay and Clover Silage in Montana

In the Gallatin Valley and in other high valleys of Montana, clover is one of the most valuable of the fodder crops. It was therefore decided to make a rather comprehensive study of this crop as grown under Montana conditions. Because of the frequent rains at the time of harvesting the second crop of the season, it is often exceedingly difficult and sometimes impossible to cure clover as hay satisfactorily, and for this reason experiments were undertaken to learn whether it could be successfully ensiled.

The first report on this work was given in Bulletin 94 by Clark. His experiments indicate that clover cures well in the silo and that for milk production clover silage furnishes a very satisfactory substitute for clover hay. The chemical studies and digestion experiments herewith reported, present another phase of this general study of red clover. Further studies on red clover as a fodder crop and on the results of curing and feeding it are in progress.

SOME RESULTS AT OTHER EXPERIMENT STATIONS

The practice of converting clover into silage has been tried at a number of experiment stations with results that seem to be fairly satisfactory, especially in the cooler and more northerly climates. Shutt, in the Ottawa Experimental Farms Report for 1902 says, "Good clover silage has succulency and palatability in its favor, besides possessing, as we have said, a large proportion of the more palatable nutrients." He also states that the reason some farmers have not been successful in their efforts to ensile clover may be traced to faulty methods of preparation, and that when silos are of sufficient depth and the material well packed down, good results may be expected. In his report are also presented analytical data showing changes which occur in the composition of clover when it is ensiled.

The experiment stations of Kansas and Colorado report that successful results may be expected when alfalfa is properly ensiled, although it is undesirable to keep alfalfa silage during the hot sum-

mer months, since the high protein content seems to be responsible for a type of "fermentation" which gives rise to a darkening in color, accompanied by a disagreeable odor. Similar results with alfalfa have been reported by others.

In some cases, unsatisfactory results with clover have been reported by experiment stations. In the Fifth Annual Report of the Vermont Station, for 1891, it is stated that "brief tests indicated that for milk and butter production clover silage is not as good as corn silage." This is in contrast to the experimental results presented by Clark in Bulletin 94.

A considerable number of experiment stations have published figures showing the chemical composition of clover hay and clover silage in their respective localities, and showing also the nutritive value and digestibility as determined by digestion experiments conducted along the usual and conventional lines. Analytical figures for clover hay are, of course, much more numerous than for clover silage. Typical examples of such data will be referred to later, in comparison with analytical results obtained at this station.

PURPOSE OF THIS EXPERIMENT

It has been fully demonstrated at this experiment station that cattle will eat and relish silage which has been properly made from medium red clover. This fact having been definitely established, it has seemed desirable to determine the composition of the average red clover crop when freshly cut and dried in the laboratory as well as when cured as hay, and then to ascertain the changes which occur where the clover is ensiled. It was also thought advisable to determine the digestibility of each, by the usual method of analyzing feed and feces and calculating the coefficient of digestibility of each of the respective food constituents.

The first clover silage made at this station was from the second cutting of the 1909 crop. The clover was cut while in bloom and handled as described in Bulletin 94. The method of handling involved cutting the clover into short pieces with a silage cutter driven by a gasoline engine. The cutter was equipped with a blower which forced the chopped material into the top of the silo. As it entered the silo, it was immediately spread evenly and thoroughly tramped down. If too dry, the clover was moistened after putting it in the silo. In this manner the second cutting has been handled each

year since 1909. The time of filling the silo has been from the middle to the latter part of September. During the winters of 1909-10, 1910-11, and 1911-12, respectively, practical feeding experiments with dairy cows were carried on, with the satisfactory results described in Bulletin 94.

PLAN OF THE EXPERIMENT

In the summer of 1911 it was decided to study the chemical changes which occur when clover is put in the silo, by analyzing a considerable number of samples of freshly cut clover and a corresponding number of samples of the silage made from the same clover. This plan was followed in the fall of 1911 and repeated in the seasons of 1912-13 and 1914-15. In all cases the samples were prepared at the time of filling the silo, which was between the 15th and 30th of September. The method of procedure was to withdraw about 10 pounds from each wagon-load, by holding a large pan under the falling particles as they entered the silo. When 30 to 40 pounds had been obtained in this way, it was thoroughly mixed, "quartered down" to about 10 pounds, and divided into two parts. Each part was sewed into a cheesecloth sack and weighed, and one was taken to the laboratory and air-dried for analysis while the other was placed in the silo. In all cases the samples placed in the silo were surrounded by an envelope of wire netting to prevent loss through breaking of the cloth sack. In this manner from twenty to twenty-four samples were taken for each period. The samples placed in the silo were located at different levels, being uniformly distributed from top to bottom at intervals of about 5 feet, three samples on each level. As rapidly as they were uncovered in the feeding process, during the winter and early spring, they were removed to the laboratory, air-dried, and prepared for analysis. This method of sampling has been found in general entirely satisfactory.

In tables I to VIII are presented analytical data showing the composition of fresh clover at the time of cutting, clover hay, and the clover ensilage, and indicating changes which occur in the ensiling and hay-curing processes. A comparison of these figures with some selected at random from the work of other experiment stations is also shown.

DISCUSSION OF THE CHANGES WHICH OCCUR DURING ENSILING

Inspection of these tables shows a considerable loss in dry matter in the ensiling process, as would naturally be expected. This is due chiefly to the breaking down of the fermentable carbohydrates and to the development of moisture from metabolic processes. Although the fresh clover contained 4.68 per cent of reducing sugars, there is no trace of any in the silage. The increase in non-protein nitrogenous compounds and the corresponding decrease in true protein indicates a breaking down of some of the proteins to the less complex nitrogen compounds. That this increase of the less complex nitrogen compounds at the expense of the protein denotes a corresponding loss of nutritive value seems very doubtful in the light of recent investigations, since it is now almost certain that proteins must be broken down to amino acids in the processes of metabolism before they can be absorbed and rendered capable of performing their functions in building up muscular tissue, while the amides probably function in a similar manner or serve as sources of readily available energy. The gain in ether extract is undoubtedly due to the formation of organic acids which are developed during the fermentation of the carbohydrates, a condition which has been repeatedly pointed out in other silage investigations. There seems to be no significant change in the mineral constituents, as denoted by the ash content of both clover and silage, while the slight increase in the percentage of crude fiber is probably caused by the decrease in the nitrogen-free extract, which includes the fermentable carbohydrates. The silage shows a slightly higher calorific value than the fresh clover. This appears entirely reasonable since the less complex carbohydrates, which are lost, have a lower percentage of carbon in their molecules than the more complex forms, which are the most resistant to the processes of fermentation. This, however, is offset by the fact that the energy contained in the less complex forms is more available for immediate use by the animal than that of the celluloses and the more complex carbohydrates.

TABLE I.—ANALYSIS OF FRESH CLOVER AND CLOVER SILAGE FOR 1911-12.
Average percentage in twenty-one samples.

	Dry matter	Crude protein	True protein	Non-protein nitrogen compounds	Reducing sugars	Pentosans	Ether extract	Ash	Crude fiber	Nitrogen-free extract	Calorific value
On Dry Matter Basis											
Fresh clover	*32.20	15.20	12.72	2.48	5.70	10.00	2.80	7.30	23.30	51.22	4191
Clover silage	*28.10	16.23	11.91	4.31	0.00	10.00	5.13	7.60	26.50	44.70	4345
Loss	4.10		0.81		5.70					6.52	
Gain		1.03		1.83			2.33	0.30	3.20		154
Gain or loss as percentage in original clover.........	-12.75	6.80	-6.36	73.80	-100.00	0.00	83.30	4.11	13.90	-12.70	3.7
On Basis of Original Sample											
Fresh clover	32.20	4.02	4.10	0.82	1.83	3.32	0.91	2.35	7.53	12.54	1350
Clover silage	28.10	4.57	3.35	1.24	0.00	2.84	1.48	2.13	7.52	10.76	1222
Loss	4.10	0.35	0.75		1.83	0.48		0.22	0.01	1.78	128
Gain				0.42			0.57				
Gain or loss as percentage in original clover.........	-12.75	-7.12	-18.30	51.20	-100.00	-14.40	62.60	-9.36	-0.13	-14.20	-9.5

*Dry matter in fresh sample.

TABLE II.—ANALYSIS OF FRESH CLOVER AND CLOVER SILAGE FOR 1912-13.
Average percentage in fifteen samples

	Dry matter	Crude protein	True protein	Non-protein nitrogen compounds	Reducing sugars	Ether extract	Ash	Crude fiber	Nitrogen-free extract	Calorific value
On Dry Matter Basis										
Fresh clover	*19.05	17.94	15.46	2.48	3.61	3.50	10.03	25.50	43.00	4260
Clover silage	*17.05	17.53	11.80	5.72	0.00	6.90	9.66	25.87	40.01	4369
Loss	2.00	0.41	3.66		3.61		0.37		2.99	
Gain				3.24		3.40		0.37		109
Gain or loss as percentage in original clover	-10.50	-2.28	-23.67	130.60	-100.00	97.20	-3.69	1.45	-6.96	2.56
On Basis of Original Sample										
Fresh clover	19.05	3.42	2.95	0.47	0.69	0.67	1.88	4.86	8.21	813
Clover silage	17.05	2.99	2.01	0.94	0.00	1.18	1.65	4.41	6.82	745
Loss	2.00	0.43	0.94		0.69		0.23	0.45	1.39	68
Gain				0.47		0.51				
Gain or loss as percentage in original clover	-10.50	-12.57	-31.85	100.00	-100.00	75.10	-12.28	-9.26	-16.93	-8.37

*Dry matter in fresh sample.

TABLE III.—ANALYSIS OF FRESH CLOVER AND CLOVER SILAGE FOR 1914-15.
Average percentage in twenty-four samples.

	Dry matter	Crude protein	True protein	Non-protein nitrogen compounds	Reducing sugars	Ether extract	Ash	Crude fiber	Nitrogen-free extract	Calorific value
On Dry Matter Basis										
Fresh clover	*24.51	17.55	15.46	2.09	4.74	2.74	10.76	25.37	43.53	4214
Clover silage	*23.42	17.02	12.14	4.88	0.00	5.16	10.00	25.98	41.74	4396
Loss	1.09	0.53	3.32		4.74		0.76		1.79	
Gain				2.79		2.42		0.61		182
Gain or loss as percentage in original clover	-4.44	-3.02	-21.48	133.5	-100.00	88.40	-7.06	2.40	-4.11	4.32
On Basis of Original Sample										
Fresh clover	24.51	4.24	3.75	0.49	1.31	0.68	2.58	6.21	10.80	1034
Clover silage	23.42	3.97	2.82	1.14	0.00	1.20	2.32	6.14	9.80	1030
Loss	1.09	0.27	0.93		1.31		0.26	0.07	1.00	4
Gain				0.65		0.52				
Gain or loss as percentage in original clover	-4.44	-6.47	-24.00	133.20	-100.00	75.42	-10.16	-1.13	-9.22	-0.39

*Dry matter in fresh sample.

TABLE IV.—AVERAGE COMPOSITION OF FRESH CLOVER AND CLOVER SILAGE THROUGHOUT THE THREE PERIODS.

(Results in percentages.)

	Dry matter	Crude protein		True protein		Non-protein nitrogen compounds		Reducing sugars		Ether extract		Ash		Crude fiber		Nitrogen-free extract		Calorific value	
		Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis
Fresh clover.	25.25	4.19	16.90	3.60	14.55	0.59	2.35	1.28	4.68	0.75	3.01	2.27	9.36	6.20	24.72	10.52	45.92	1066	4222
Clover silage.	22.86	3.84	16.93	2.73	11.95	1.11	4.97	0.00	0.00	1.29	5.73	2.03	9.09	6.02	26.12	9.12	42.15	999	4370
Gain or loss.	-2.39	-0.35	0.03	-0.87	-2.60	0.52	2.62	-1.28	-4.68	0.54	2.72	-0.24	-0.27	-0.18	1.40	-1.40	-3.77	-67	148

TABLE V.—CHANGES IN THE COMPOSITION OF RED CLOVER DURING ENSILING.

Gains and losses of constituents calculated to the percentage of the constituent in the original sample.

Period	Dry matter	Crude protein		True protein		Non-protein nitrogen compounds		Reducing sugars		Ether extract		Ash		Crude fiber		Nitrogen-free extract		Calorific value	
		Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis
1911-12	-12.75	-7.12	6.80	-18.30	-6.36	51.2	73.8	-100.0	-100.0	62.60	83.3	-9.36	4.11	-0.13	13.90	-14.20	-12.7	-9.5	3.70
1912-13	-10.50	-12.57	-2.28	-31.85	-23.67	100.0	130.6	-100.0	-100.0	75.10	97.2	-12.23	-3.69	-9.26	1.45	-16.93	-6.96	-8.37	2.56
1914-15	-4.44	-6.47	3.02	-24.00	-21.48	133.2	133.5	-100.0	-100.0	75.42	88.4	-10.16	-7.06	-1.13	2.40	-9.22	-4.11	-0.39	4.32
Average	-9.23	-8.72	1.50	-24.72	-17.17	94.8	112.6	-100.0	-100.0	71.04	89.6	-10.58	-2.21	-3.51	5.92	-13.45	-7.92	-6.09	3.53

CHANGES WHEN RED CLOVER IS CURED AS HAY

Table VI gives the composition of clover hay grown on the college farm. This clover is from the same field as that which was put into the silo but it was cured in the field by drying.

The figures in Table VII, comparing the freshly cut clover, the clover hay, and the clover silage, show a lower protein content for

TABLE VI.—ANALYSES OF CLOVER HAY.
(Results in percentages.)

Number	Dry matter	Crude protein	True protein	Non-protein nitrogen compounds	Ether extract	Ash	Crude fiber	Nitrogen-free extract	Calorific value
				On Dry Matter Basis					
1		14.70	12.85	1.85	2.17	8.80	21.98	54.35	4285
2		15.40	13.70	1.70	2.58	8.86	22.56	50.60	4325
3		14.49	13.04	1.45	2.82	8.96	22.91	51.82	4068
4		15.29	13.29	2.00	3.08	8.87	22.39	50.37	4278
5		13.65	12.33	1.32	2.91	8.31	24.74	50.40	4280
Ave. ..		14.71	13.04	1.66	2.71	8.76	22.92	51.51	4247
				On Basis of Original Sample					
1	83.99	12.34	10.79	1.55	1.83	7.39	19.86	42.51	3599
2	84.86	13.06	11.63	1.43	2.19	7.53	19.56	42.53	3670
3	86.17	12.49	11.23	1.25	2.43	7.73	20.34	43.18	3506
4	85.55	13.09	11.37	1.72	2.64	7.58	19.81	42.43	3659
5	86.91	11.86	10.72	1.14	2.53	7.22	21.51	43.79	3721
Ave. ..	85.50	12.57	11.15	1.42	2.32	7.49	20.22	42.89	3631

TABLE VII.—COMPARISON OF CONSTITUENTS IN THE DRY MATTER OF FRESHLY CUT CLOVER, CLOVER HAY AND CLOVER SILAGE.
(Results in percentages.)

Sample	Crude protein	True protein	Non-protein nitrogen compounds	Ether extract	Ash	Crude fiber	Nitrogen-free extract	Calorific value
Freshly cut clover.....	16.90	14.55	2.35	3.01	9.36	24.72	45.92	4222
Clover hay	14.71	13.04	1.66	2.71	8.76	22.92	51.51	4247
Clover silage	16.93	11.95	4.97	5.73	9.09	26.12	42.15	4370

the clover hay than for the silage or the freshly cut clover. The nitrogen-free extract is higher in the clover hay, while ash, fiber, and ether extract show slight losses. Some loss in non-protein nitrogenous compounds occurs during the curing of the clover as hay but these compounds are increased during the ensiling of clover. The calorific value is highest in the silage and lowest in the freshly cut clover.

COMPARISON OF MONTANA CLOVER WITH SOME FROM OTHER STATES

Table VIII, which presents analytical data showing the composition of clovers at some of the other experiment stations, indicates that there is considerable variation in the food constituents of clover in different sections of the country. The ether-extract content of clover hay, for example, varies from 0.64 per cent of the dry sample at Ottawa, Canada, to 3.9 per cent at the Virginia station. Crude protein varies from 10.47 per cent in Washington to 15.19 per cent in Canada. Similar variations with respect to crude fiber and nitrogen-free extracts are noticeable, while the variation in ash content is less than that of any of the other constituents.

TABLE VIII.—COMPARISON OF ANALYSES OF CLOVER HAY AND CLOVER SILAGE FROM DIFFERENT EXPERIMENT STATIONS.

(Results in percentages.)

Experiment Station	Material analyzed	Ash	Crude protein	Crude fiber	Ether extract	Nitrogen-free extract
	On Dry Matter Basis					
Maine	Alsike clover hay	9.14	14.96	31.42	1.93	42.55
Maine	Alsike clover silage	10.39	12.10	37.18	3.88	36.45
Utah	Red clover hay	8.75	14.02	34.63	2.58	40.02
Utah	Red clover silage	9.20	14.90	29.10	4.08	42.72
Ottawa, Canada	Red clover hay	9.16	15.19	41.27	0.64	33.74
Ottawa, Canada	Red clover silage	10.70	16.94	45.89	1.01	25.46
Montana	Red clover hay	8.76	14.71	22.92	2.71	51.41
Montana	Red clover silage	9.09	16.93	26.12	5.73	42.15
U. S. Dept. Agr.	Red clover hay	6.80	12.46	28.20	2.08	42.77
Virginia	Red clover hay	7.30	14.50	29.10	3.90	45.20
North Dakota	Red clover hay	14.22	13.75	26.84	3.79	41.40
Washington	Red clover hay	7.06	10.47	37.32	1.86	43.29

These analytical figures from other stations were selected at random from the large number of published analyses of red clover hay which are available. It may be observed that the Montana product compares very favorably with the others which happen to have been selected for comparison. Of the red clover hays reported, it is second highest in protein, highest in nitrogen-free extract, and lowest in fiber; it is fourth with respect to ether extract, and second in ash content. It is recognized that the differences in fiber and nitrogen-free extract may be partly due to different analytical methods, but the figures showing differences in crude protein, which is the most valuable food constitutent, should be of real significance.

A comparison of the differences between the hay and silage of each of the four stations which report analyses of both products indicates the probability that in different climates and under different weather conditions we may expect varying changes in the food constituents.

DIGESTIBILITY OF CLOVER HAY AND SILAGE

The composition of the average red clover crop having been determined, together with the changes which may normally be expected to occur during its ensiling and also when it is cured as hay, under Montana conditions, it was thought that a determination of the coefficients of digestibility of clover hay and silage would furnish additional information which should be useful in estimating the feeding value of red clover in this section of the country.

Work of this nature was done in the winter of 1912-13 and repeated in a slightly different way during the winter of 1914-15. A two-year-old Hereford steer was used in the first experiment and a Shorthorn of the same age in the second. Both experiments were conducted in the usual manner, which involves the analysis of the feeds, and the collection and analysis of the feces accumulating throughout the feeding period.

TABLE IX.—DIGESTIBILITY EXPERIMENTS. PERIODS AND RATIONS FOR 1912-13.

Period	Dates	Total rations
I	Mar. 31 to Apr. 10	300 lbs. clover silage and 80 lbs. timothy hay.
II	Apr. 23 to May 3	140 lbs. timothy hay.
III	May 24 to June 3	300 lbs. clover silage and 80 lbs. timothy hay.
IV	June 16 to June 26	140 lbs. timothy hay.

TABLE X.—DIGESTIBILITY EXPERIMENTS. PERIODS AND RATIONS FOR 1914-15.

Period	Dates	Total rations
V	Jan. 4 to Jan. 14	300 lbs. clover silage and 80 lbs. clover hay.
VI	Jan. 29 to Feb. 8	160 lbs. clover hay.
VII	Feb. 26 to Mar. 8	230 lbs. clover silage and 110 lbs. clover hay.
VIII	Mar. 24 to Apr. 3	500 lbs. clover silage.
IX	Apr. 21 to May 1	190 lbs. clover hay.
X	May 19 to May 29	175 lbs. clover hay.

TABLE XI.—COEFFICIENTS OF DIGESTIBILITY

Period	Dry matter	Crude protein	True protein	Non-protein nitrogen compounds	Ether extract	Crude fiber	Ash	Nitrogen-free extract	Calorific value
				Clover Silage, 1912-13					
I	68.55	68.78	53.50	100	78.98	59.63	44.10	78.00	70.30
III	67.00	71.65	50.75	100	78.05	45.00	53.60	80.00	67.25
Ave.	67.77	70.24	51.13	100	78.52	52.31	48.85	79.00	68.78
				Timothy Hay, 1912-13					
II	55.70	52.10	43.40	100	56.60	52.48	38.25	62.60	53.70
IV	60.40	55.50	47.80	100	73.00	60.40	40.80	63.90	59.70
Ave.	57.87	53.80	45.60	100	64.80	56.44	39.53	63.25	56.70
				Clover Silage, 1914-15					
V	65.23	66.45	55.04	100	74.01	46.75	34.35	77.27	64.23
VII	60.93	61.16	45.17	100	80.11	46.53	49.14	70.50	58.68
VIII	65.55	67.45	56.18	100	79.84	55.08	47.45	74.42	66.17
Ave.	63.90	65.02	52.13	100	77.99	49.45	43.65	74.07	63.03
				Clover Hay, 1914-15					
VI	67.59	69.60	65.86	100	61.43	50.87	50.39	78.08	67.02
IX	65.80	67.59	62.70	100	59.87	50.22	50.51	75.51	64.34
X	65.21	64.97	61.24	100	62.71	47.37	48.97	76.85	63.18
Ave.	66.20	67.39	63.27	100	61.34	49.48	49.96	76.81	64.85
				Average for All Periods					
1912-13	67.77	70.24	51.13	100	78.52	52.31	48.85	79.00	68.78
1914-15	63.90	65.02	52.13	100	77.99	49.45	43.65	74.07	63.03
Ave.	65.84	67.63	51.63	100	78.25	50.88	46.25	76.53	65.91

In the first experiment, in the winter of 1912-13, known amounts of timothy hay were fed with the silage, since it was feared that silage alone might prove too laxative. Thus, the determination of the digestibility of clover silage involved determinations of the digestibility coefficient of both feeds and the introduction of a correction for the timothy hay.

In the second experiment, in the winter of 1914-15, known amounts of clover hay and silage were fed exclusively in their respective periods, and the coefficients of digestibility determined directly.

In each experiment the animal was placed in a stall made for the purpose, following specifications supplied by the Division of Animal Nutrition of the Pennsylvania Experiment Station, which also kindly sent a worn-out dung duct and urine funnel to be used as patterns.

In all experiments the animal was given a period of not less than ten days in which to accustom himself to the feed and to develop a normal appetite and digestion. The experimental digestion periods were ten days each. The periods and rations for the first experiment, in 1912-13, are shown in Table IX. In the second experiment, in 1914-15, clover hay and clover silage were used as shown in Table X.

Samples of the feed for each period were analyzed in the usual manner, and the feces were collected twice during each period and analyzed. From the analyses of the feeds, the total amount of each food constituent ingested by the steer was ascertained, and the analyses of the feces by the same methods indicated the undigested portion of each constituent. From these data was determined the percentage of each constituent digested by the steer, which value is known as the coefficient of digestibility. The non-protein nitrogenous compounds are assumed to be wholly digestible.

SUMMARY OF THE ANALYTICAL RESULTS

In Table XI are shown the coefficients of digestibility for each period, and averages for the different periods in which the same feed was used. Inspection of these figures indicates that, with the important exception of the albuminoids, there is very little, if any, difference between the digestibility of red clover hay and red clover silage. The noticeably lower coefficient of digestibility for the true proteins in the case of the silage indicates a possibility that the proteins may undergo changes of a "denaturing" character during the process of ensiling.

The fact that the ether extract of the silage shows a much higher digestibility than that of the hay must be due to the previously mentioned development of ether-soluble organic acids during the ensiling process rather than to any changes in the fats themselves.

CONCLUSIONS

1. The most important chemical changes occurring during the ensiling of red clover are an increase in the percentage of moisture, a disappearance of the reducing sugars, a loss in the nitrogen-free extract, and a slight gain in fiber.

2. When clover is cured as hay there is a significant loss in protein, a considerable gain in nitrogen-free extract, and a slight loss in ash, crude fiber, and ether extract.

3. With respect to the amounts of its food constituents, Montana red clover hay has a high rank when compared with typical examples of red clover hays from other sources.

4. The experimental results indicate that when red clover is ensiled, there occur changes in the proteins which result in a noticeable lowering of the coefficient of digestibility for this, the most important of food constituents.

5. In a cool, dry climate red clover may be satisfactorily ensiled when weather conditions interfere with curing it as hay. The process of ensiling does not result in very serious loss, either in food value or in the digestibility of most of the constituents discussed.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

BULLETIN NO. 118 SEPTEMBER, 1917

Sunflower Silage for Dairy Cows

A Preliminary Report

BY

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Sunflower Silage for Dairy Cows

In the spring of 1915 a small area at the Experiment Station was seeded to Giant Russian sunflowers. The yield per acre under irrigation was approximately 36 tons of green material. The crop was tested in a limited way as a soiling feed for dairy cows to supplement the pastures and also as ensilage.

Encouraged by the satisfactory results obtained, some three acres were seeded to sunflowers in the spring of 1916. They were planted in rows 28 inches apart at the rate of 20 pounds per acre. The crop was cultivated but not irrigated.

A portion of the field was cut and fed to the dairy cows as a supplement to the pasture during the latter part of the grazing season. The sunflowers so used were first run through a feed cutter. The cows ate the green sunflowers readily, consuming from 40 to 90 pounds per head daily, kept up the milk flow, and apparently did well on the feed.

The green sunflowers were fed in comparison with green corn and the results indicated that the sunflowers and corn were of equal feeding value pound for pound. Only about 5 per cent of the sunflowers were in bloom so there was no seed or grain in either case.

The remainder of the crop was harvested after the first hard frost and yielded 22 tons per acre. The percentage of bloom was approximately the same as stated above. An ordinary ensilage cutter was used in filling the silo. The ensilage was in first class condition when the silo was opened in March and in practically all cases it was eaten with relish at the first feeding. In a few cases it required several days to accustom the cows to the change from oat and pea ensilage.

In order to determine the relative value of ensilage made from sunflowers, two lots of cows were fed. Each lot contained seven cows as nearly equal as possible in breed, age, weight, condition, period of lactation, pregnancy, milk production, and fat test. Lot I received grain and clover hay and Lot II, grain, clover hay, and sunflower ensilage. The grain fed was a mixture of oats, 5 parts; malt sprouts, 2 parts; and bran, 3 parts. The clover used was choice alsike. At the end of 28 days the lots were reversed and Lot

I was fed grain, clover hay, and sunflower ensilage, and Lot II, grain and clover hay, for 28 days. This change was made to eliminate as far as possible variations due to individuality among the cows. A preliminary feeding period of 7 days was given at the beginning of each period of the experiment in order to accustom the animals to the change in feed. Individual weights were taken three days at the beginning and at the close of each period, and the averages of these weighings were taken as the initial and final weights. Individual records of milk produced and fat tests were used in order to determine the production.

In order to simplify the discussion of results, the data obtained from Lot I and Lot II while fed grain and clover hay are combined in one table. Likewise, the data obtained from Lots I and II while fed grain, clover hay, and sunflower ensilage are combined.

Table I, giving the data for the period when only grain and clover hay were fed, shows that the 14 cows gained a total of 155 pounds or an average of 11 pounds per cow during the 28-day period. The 14 head consumed 5,140 pounds of grain and 8,243 pounds of clover hay, which is practically a daily average of 13 pounds of grain and 21 pounds of clover hay per cow. The total production during the period was 13,084.6 pounds of milk and 542 pounds of fat, a daily average of 33.37 pounds of milk and 1.382 pounds of butter fat per cow.

The data presented in Table II, covering the period when grain, clover hay, and sunflower ensilage were fed, show that the 14 cows gained a total of 81 pounds, or an average of approximately 6 pounds per head during the 28 days. The 14 head consumed a total of 5,134 pounds of grain, 4,778 pounds of clover hay, and 13,182 pounds of ensilage, which is a daily average per cow of approximately 13 pounds of grain, 12 pounds of hay, and 34 pounds of ensilage. The total milk production was 13,464.8 pounds and 571.92 pounds of butter-fat, which is an average of 34.35 pounds of milk and 1.459 pounds of butter-fat per head daily.

TABLE I.—DATA FOR LOTS I AND II WHILE ON RATION OF GRAIN AND CLOVER HAY.

(Results in pounds.)

Cow No.	Initial weight	Final weight	Total feed eaten		Average daily feed eaten		Milk		Fat	
			Grain	Hay	Grain	Hay	Total 28 days	Daily average	Total 28 days	Daily average
1	802	817	327	414	11.6	14.7	625.4	22.33	39.18	1.399
2	827	845	287	497	10.2	17.7	624.0	22.28	32.75	1.169
3	1220	1248	476	684	17.0	24.4	1432.4	51.16	47.63	1.701
4	1189	1230	441	689	15.7	24.6	1212.1	43.29	53.81	1.921
5	1219	1280	441	692	15.7	24.7	1170.5	41.80	41.78	1.492
6	1144	1137	357	461	12.7	16.4	808.5	21.73	33.37	1.192
7	1034	1034	293	554	10.4	19.7	903.3	32.26	33.39	1.192
8	826	816	280	470	10.0	16.7	639.2	22.82	39.09	1.396
9	713	700	168	371	6.0	13.2	428.3	15.29	21.91	0.782
10	1149	1144	474	669	16.9	23.8	1314.9	46.60	54.85	1.958
11	1151	1134	448	670	16.0	23.9	1099.7	39.27	43.09	1.538
12	1309	1324	392	710	14.0	25.3	987.5	35.26	32.04	1.144
13	1259	1281	336	690	12.0	24.6	783.4	27.97	25.37	0.906
14	1161	1168	420	672	15.0	24.0	1055.4	37.69	43.74	1.562
Total	15,003	15,158	5,140	8,243			13,084.6		542.00	
Ave. for one cow	1071.6	1082.7	367.1	588.7	13.0	21.0	934.6	33.37	38.71	1.382

TABLE II.—DATA FOR LOTS I AND II WHILE ON RATION OF GRAIN, CLOVER HAY, AND SUNFLOWER ENSILAGE.

(Results in pounds.)

Cow No.	Initial weight	Final weight	Total feed eaten			Average daily feed eaten			Milk		Fat	
			Grain	Hay	Silage	Grain	Hay	Silage	Total 28 days	Daily average	Total 28 days	Daily average
1	833	838	308	260	795	11.0	9.2	28.3	590.0	21.07	50.35	1.798
2	855	860	252	273	765	9.0	9.7	27.3	597.7	21.34	31.04	1.108
3	1249	1232	476	388	1227	17.0	13.8	43.8	1343.1	44.39	59.01	2.107
4	1238	1268	420	389	1248	15.0	13.8	44.5	1132.2	40.43	47.54	1.698
5	1275	1260	420	388	1251	15.0	13.8	44.6	1066.6	38.09	39.68	1.417
6	1125	1138	336	279	822	12.0	9.9	29.3	733.9	26.21	27.05	0.966
7	1061	1068	306	331	1085	10.9	11.8	38.7	809.3	28.90	33.03	1.179
8	822	825	301	367	431	10.7	13.1	15.3	712.0	25.42	41.46	1.480
9	735	701	213	216	235	7.6	7.7	8.3	483.1	17.25	22.79	0.814
10	1151	1155	450	397	1117	16.0	14.1	39.8	1574.5	56.23	56.27	2.009
11	1142	1145	469	382	996	16.7	13.6	35.5	1229.5	43.91	46.96	1.677
12	1282	1303	427	390	1130	15.0	13.9	40.3	1119.4	39.97	44.78	1.599
13	1217	1242	336	327	1077	12.0	11.6	38.4	924.1	33.00	30.01	1.071
14	1145	1176	420	391	1003	15.0	13.9	35.8	1149.4	41.05	41.95	1.498
Total	15,130	15,211	5,134	4,778	13,182				13,464.8		571.92	
Ave. for one cow	1080.7	1086.5	366.7	341.2	941.5	13.	12.1	33.62	961.77	34.35	40.851	1.459

Table III gives a brief summary of the entire experiment. The figures show that the 14 cows, while receiving the ration of grain and clover hay, gained on the average 5 pounds more per head in 28 days than while they received the ration containing sunflower ensilage. The grain ration was the same throughout the entire experiment and an average daily feed of 34 pounds of sunflower ensilage effected a daily saving of 9 pounds of clover hay per cow. There was a slight increase in production while the cows were receiving the sunflower ensilage. This increase amounted to 0.98 of a pound of milk and 0.077 of a pound of butter-fat daily. This difference was too small to be of significance except as indicating that there was no reduction in milk or butter-fat production due to the feeding of sunflower ensilage in place of a part of the clover hay in the ration. The data presented indicate that under the conditions of this experiment 1 pound of choice clover hay is equal to 3¾ pounds of sunflower ensilage.

TABLE III.—SUMMARY OF THE EXPERIMENT

	Lot I	Lot II
	Grain and clover hay	Grain, clover hay and sunflower ensilage
Number in each lot	14	14
Days on test	28	28
Average initial weight	1072	1081
Average final weight	1083	1087
Average gain for period	11	6
Average daily grain per head	13	13
Average daily clover hay per head	21	12
Average daily sunflower silage per head	....	34
Average daily milk per cow	33.37	34.35
Average daily butter-fat per cow	1.382	1.459

The milk from cows fed sunflower ensilage was sampled and tested for flavor but no objectionable flavors or change in the milk could be detected.

The results with the Giant Russian sunflowers as a forage crop have been so encouraging that we are led to make this preliminary report. It is realized that further experimental work is necessary

before definite conclusions as to the feeding value of sunflowers as a soiling or ensilage crop can be drawn. More extensive feeding tests are planned for the winter of 1917-18.

Complete digestion trials were conducted by the animal husbandry and chemistry departments to determine the digestibility of sunflower ensilage and the results will be available in the near future.

The agronomy department has in progress comprehensive tests to determine the rate and method of seeding that will produce the greatest yield, lowest fiber content, and early maturity.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

BULLETIN NO. 119 SEPTEMBER, 1917

Hairlessness and Goiter in New-Born Domestic Animals

BY

HOWARD WELCH

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PREFACE

For some fifteen to twenty years reports have come to the Experiment Station of occasional losses of young pigs born without hair. It was not, however, until the State was settled by farmers that the complaints became numerous and definite enough to lead us to suspect some unusual cause.

The veterinary department outlined a project on this subject in the summer of 1914, the chemistry department cooperating. Mr. G. E. Smith, assistant in the chemistry department, was assigned to the analytic work on this project in the early part of 1916. The manuscript was prepared for publication in the fall of 1916, but as the results of some of the tests were rather inconclusive it was decided to await the results of another series of tests to be made in various parts of the State during the fall and winter months. The results of these tests are now all at hand and are embodied in this report.

This is a report of progress. The experiment is being continued to get further evidence as to the value of the treatment and, if possible, some further explanation of the cause of the trouble.

F. B. Linfield
Director

4-5-1932

Hairlessness and Goiter in New-Born Domestic Animals

It has been known for a number of years that in certain sections of the Northwestern States—Washington, Idaho, North Dakota, South Dakota, Minnesota, and Montana—the new-born of all the domestic animals in certain sections were in some way or other defective. The new-born pigs were hairless and seldom lived; the calves were frequently hairless and more frequently had goiter or "big-neck." The young of goats and sheep were similarly affected, while the new-born foals, though showing neither the hairlessness nor goiter, were weak, seldom able to stand, and usually died.

In Montana the loss is probably heaviest in pigs, it being estimated that about 100,000 young pigs annually die from this cause. In some localities pigs are the only domestic animals affected, while in others the pigs may be normal and the lambs affected, etc. It is a disease of definite localities, occurring in Montana in the drainage basin of the Yellowstone, the lower Missouri, the Musselshell, and some of the smaller tributaries, as indicated on the accompanying map. There are many scattered cases of hairless pigs, lambs, etc., which are not included in these districts, but they do not constitute over 5 per cent of the total loss.

The affected area is sharply defined in some cases, less in others. Sometimes it is a narrow creek bottom, half a mile wide, while the bench-land on either side is unaffected. In some cases the rancher can save his pig crop by moving the pregnant sows a mile or two out of the affected district during the gestation period. In the lower Yellowstone Valley the affected area is from seventy-five to one hundred and fifty miles wide and less sharply defined, but all through this region are unaffected spots—a ranch, several ranches, or a whole community—where hairless pigs have never occurred though large numbers of hogs are raised.

This malady is subject to curious variations. A rancher one year may lose 95 per cent of his pigs and the next year with the same breeding stock, the same ranch conditions, and feed and water from the same source, raise an entirely normal bunch of pigs. Pigs born in March and April are much more frequently affected than those born in May and June, and fall pigs are frequently normal even in the badly affected districts.

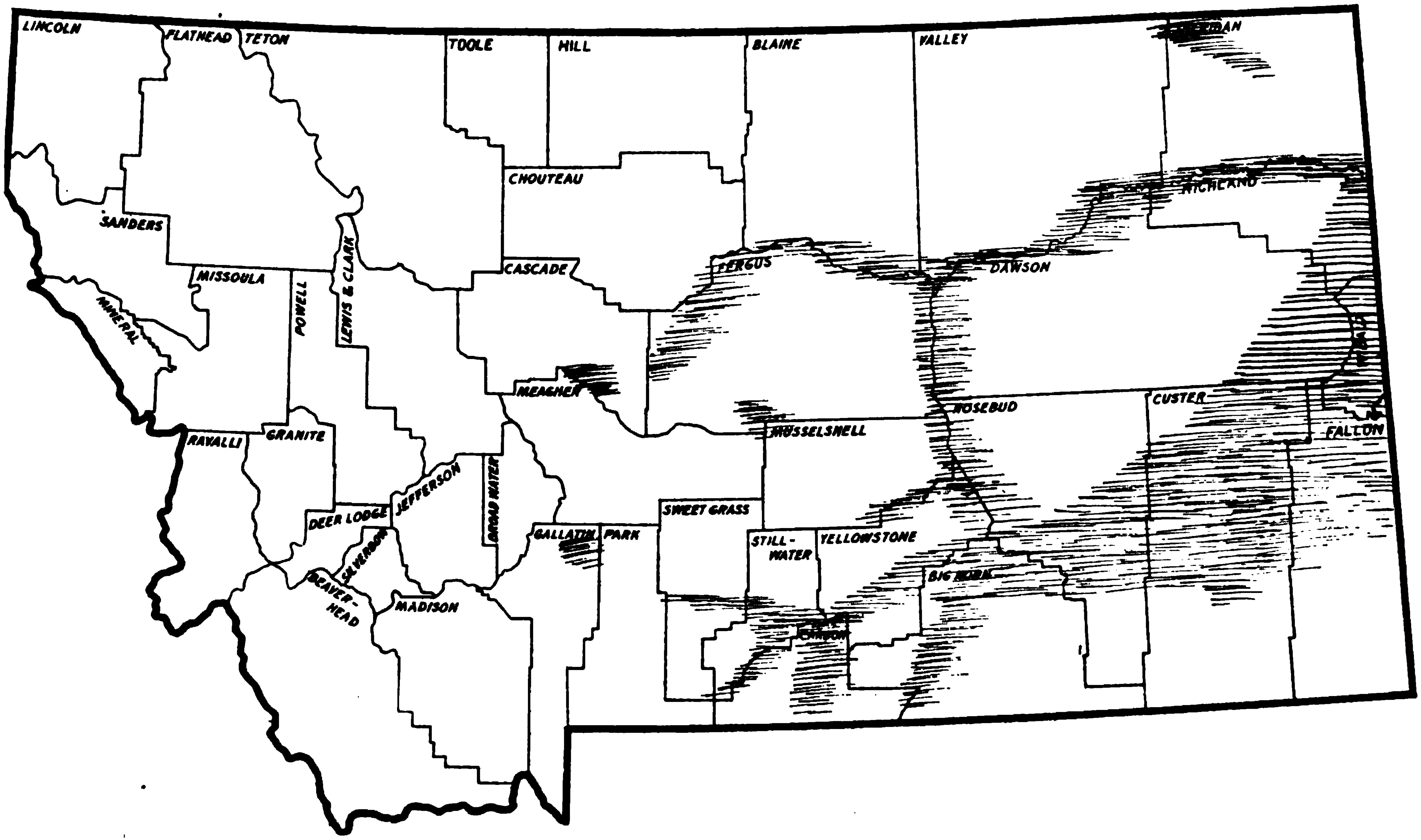

FIG. 1. The shaded areas indicate the approximate distribution of goiter and hairlessness in new-born animals in Montana. There are many districts in the shaded areas where this disease does not occur, and many isolated cases have occurred in other parts of the State.

The most puzzling feature is the variation in a single pen of pregnant sows. If, for instance, six sows are kept in the same pen, fed and cared for under identical conditions in the affected area, the results at farrowing time may be as follows: Three sows may produce normal, vigorous litters; two sows may produce pigs that are hairless and weak, and that die in a few hours; and the sixth sow, producing nine pigs, may have four hairless, three normal, and two partly haired out. These last may live if cared for, but will be slow to grow and develop.

FIG. 2. Litter of seven pigs, three normal and four nearly hairless.

In the affected areas, sows will produce hairless pigs under the widest range of conditions,—when kept in pens or running at large; fed on any combination of grain, hay, roots, etc.; ranging on alkali land or land free from alkali; fed alfalfa or not. The occurrence of hairless pigs appears to be independent of any system of feed, care, or management as yet practiced in this State. It is true that the vigor and vitality of the pig depend in a measure upon the type of ration supplied to the sow, and that weak and hairless pigs have been experimentally produced by extreme types of rations, but the hairlessness characterizing this disease is not

of the same nature and is not the result of feeding any particular grain.*

Hairless pigs are not the result of abortion. The pregnant sow carries the pigs to the full term of the gestation period. Many ranchers report that the pregnant sows carry the pigs four to seven days longer than the average period and a great many sows die at farrowing time. Many of the pigs are born dead, others die in an hour or two, and very few live more than twenty-four to thirty-six hours. Born of apparently normal sows, they are strikingly weak and low in vitality. The accompanying illustration shows a typical litter.

FIG. 3. Typical litter of hairless pigs.

POST-MORTEM FINDINGS

Post-mortem examinations show that hairless pigs are of full size, occasionally larger than the average. The head and neck are larger than normal and the skin seems to be in folds around the throat and shoulders. The most striking thing in the appearance of the specimen is the absence of hair. Except for a few tactile hairs on the nose and a few around the eyes, the skin is smooth, shiny, and bald. A very close examination frequently reveals a

*Hart, Miller and McCollum, of the Wisconsin Experiment Station, have conducted experiments showing that wheat, particularly the wheat embryo, when fed in certain proportions to hogs, interferes with the development of the growing animal and arrests the normal growth of the fetus, many of the young being born hairless. Wisconsin Exp. Sta. Res. Bul. No. 17.

few scattered hairs along the nape of the neck and the crown of the head. The hairless condition is very variable, from an almost absolutely hairless fetus to a pig with a thin coat and through all gradations to the normal. No two hairless pigs, even in the same

FIG. 4. Hairless pig (Yorkshire).

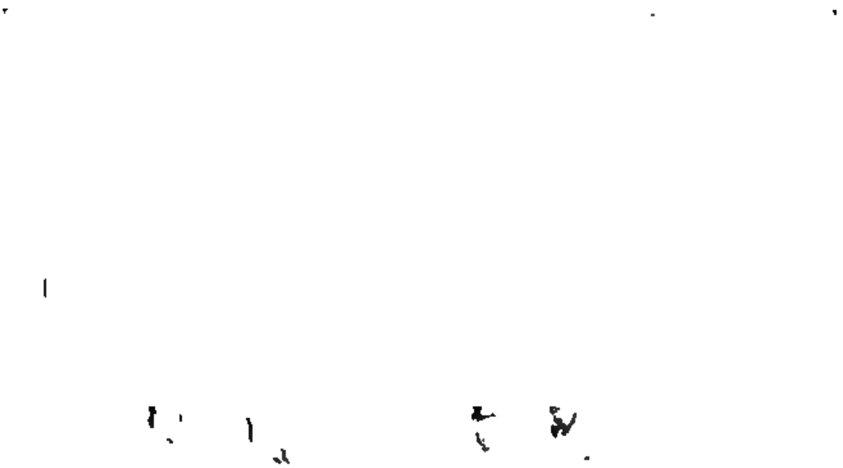

FIG. 5. Hairless pig (Berkshire).

litter, present exactly the same amount of development of coat. In most cases a close examination will show hairs present, though rudimentary, over a large part of the body.

The skin, particularly around the shoulders, is thick and can not be raised from the body with the thumb and finger except in large folds. It feels pulpy, jelly-like. On making an incision, the skin is seen to be from one-fourth to one-half inch in thickness and not clearly separable from the underlying connective tissues. It is semi-transparent and seems oedematous, but no fluid escapes on incision. The skin over the posterior part of the body is more nearly normal, though frequently somewhat pulpy.

The hoofs are thin-walled, brittle, and plainly in an undeveloped condition.

The muscles are cyanotic, a deep blue-red, which fades to a normal pink on exposure to air.

In every case examined, the heart had a persistent foramen ovale. Normal pigs of the same age showed a persistent foramen in about 2 per cent of the cases examined.

The lungs are in many cases atelectatic, as many of these pigs are dead when born.

There is a wide variation in the size of the thymus, but it is seldom as small as in a normal pig of like age.

The thyroid presents a most constant and unvarying enlargement. Thyroids from normal pigs, from one to twenty-four hours old, average 1 cm. in length, 0.7 cm. in diameter, about 0.2 gram in weight, and are reddish or pink in color. Thyroids from hairless pigs average 2.5 cm. in length, 1.5 cm. in diameter, 2 grams or more in weight, are dark red to almost black in color and highly vascular. In every case the pigs that were the most extremely bald showed the greatest thyroid enlargement, in many cases showing a marked enlargement of the throat externally. In lambs and calves the enlarged thyroid is usually very conspicuous, the thyroid of a hairless calf being frequently four to five inches in diameter, though the normal thyroid is scarcely one-half inch in thickness. To make certain that this thyroid enlargement was constant, about one hundred and fifty hairless pigs were obtained, through the cooperation of interested stockmen, and carefully examined. About one hundred normal pigs, one to twenty-four hours of age, were

collected from local breeders. These pigs were normal in every way and were used as a basis for comparison. It was not possible to get live hairless pigs for examination or observation, as most of them live only an hour or so and it is very difficult to locate a new-born litter and reach them before their death.

Microscopically, the enlarged thyroid shows a material increase in the connective tissue stroma and the size and number of blood vessels. The size of the gland is not entirely due to this, however, as the number of acini is undoubtedly increased, especially in the thyroid of hairless lambs. The acini contain very little colloid material, but in many cases contain debris that appears to be desquamated epithelial cells. The acini, from a normally rounded, oval shape, have become distorted, convoluted, and branched. The epithelium, instead of the normal cubical type, is columnar, especially in what appear to be the new acini. In a few instances, several of the acini appeared to have become confluent so that a large cystic cavity formed. In the lamb thyroid these cysts are plainly visible to the naked eye, and in no instance in the lamb thyroid was the increase of the connective tissue stroma so marked as in the thyroid of the pig.

CAUSE OF HAIRLESSNESS

In taking up the search for the cause of hairlessness in the new-born, the possibility of contagious abortion was considered first of all. Blood samples were drawn from sows within a week after producing hairless pigs, but no reaction was obtained in the complement fixation test for contagious abortion. Repeated attempts to isolate the bacillus of contagious abortion failed, though material was taken from the placenta and from stomach contents of the hairless pigs. Further investigation along this line was dropped on account of the fact that the field work strongly indicated that something other than transmissible disease was responsible for the trouble. There are not, in our entire field observations, any facts which would indicate a communicable disease, but, on the other hand, all evidence would tend to disprove such a theory. With the same environment, some litters are hairless and others are normal; in the same litter are affected and unaffected pigs; sows removed from the affected area during the gestation period produced normal pigs, whereas those which remained produced hairless pigs. All

these facts tend to eliminate transmissible disease as a possible factor.

A considerable part of the affected district contains a great deal of alkali and many stockmen have asserted that alkali is the cause of the malady, but this can not be considered, for large numbers of normal pigs are born in alkali districts in other parts of the State.

Likewise, as alfalfa grows luxuriantly in eastern Montana and in many cases the sows had little else to eat, it has been stated that alfalfa would produce hairlessness in pigs. But in many other sections of the State alfalfa is the principal food for hogs and no hairlessness in pigs ever occurs.

TABLE I.—EFFECT OF VARIOUS RATIONS.

Lot. No.	No. of sows	Grain	Hay	Tankage (per cent)	Water	Exercise	Hairless litters	Normal litters
1	4	Wheat Oats	Alfalfa	10	River	In pens	3	1
2	6	Oats	Alfalfa	10	River	In pens	2	4
3	11	Barley Oats	Alfalfa	12	Well	In pens	8	3
4	7	Corn Barley Oats	Alfalfa	10	Well	Pasture	6	1
5	8	Wheat	Alfalfa	....	River	Pasture	4	4
6	8	Wheat Oats	Alfalfa	10	River	Pasture	8	--

It did not seem likely that the hairlessness and goiter could be due to a dietary disturbance but cooperative feeding experiments were carried out to determine whether that were possible. Six bunches of sows in representative affected areas in different parts of the State were fed on ranch feed and water, with tankage supplied to better balance the ration. The results of this experiment as shown in Table I would indicate that goiter and its associated conditions, in these cases at least, were not caused by an unbalanced ration.

There was also the possibility of an extreme soil or water condition to be considered. We collected some forty samples of soil and water from different districts, all of which were known as affected areas, and analyzed them. Nothing could be deduced from the tabulated results. Some soils were high in alkali, others very low. Some were very abundant in lime salts, others had a normal lime content. Analyses of water samples from badly affected areas were almost exactly like those of samples taken where no hairless pigs had ever occurred. Analyses of soils likewise failed to show anything constant, or anything which could be correlated with the goiter trouble, and this line of investigation was therefore dropped.

RELATION OF GOITER AND HAIRLESSNESS

The most conspicuous and constant feature of this malady is the goiter, or enlargement of the thyroid gland, and a search for the cause of this thyroid disturbance was the most promising line of investigation.

For many years the functions of this gland have been studied and the most definite conceptions of its functions have been obtained by observing the results following a total removal of the gland.

In 1878, William M. Ord* described five cases in adults in which he had found atrophy of the thyroid gland, the follicles being destroyed through the swelling connective tissue. An invariable symptom was the thickening and swelling of the skin, which occurred usually in the face but sometimes extended to the extremities and other parts of the body. The thickening could not be regarded as oedema; when the swollen skin was cut, no serum flowed out. On account of the invariable occurrence of this symptom, Ord called the disease myxoedema. Other trophic disturbances were also present—baldness, atrophy of the nails and teeth, etc.

In April, 1883, J. L. Reverdin and A. A. Reverdin,** two Swiss doctors, published in detail the results of removing goiters in twenty-two cases. Of these, fourteen were complete, i. e., excision of the entire thyroid gland, both the diseased part and the sound tissue. The symptoms bore a striking resemblance to those of

*Medico-Cherurg. Trans. 2nd Ser., Vol. XLIII, p. 57 (1878).

**Revue med. d. l. Suisse romande, 3 ieme, Ann. pp. 169, 223, 309.

myxoedema—swelling of the skin of the face and extremities, anemia, etc.

At about the same time Kocher, another Swiss doctor, was engaged in performing the same operation of complete extirpation at Berne.* The symptoms which occurred after complete extirpation were identical with those described by Reverdin. He states that "soon after their dismissal from the hospital, or in a few cases, not until four or five months afterwards, the patients began to complain of lassitude, weakness and weight in the limbs. * * * At the same time, swellings appear on the face, hands, feet * * *. The whole skin seems swollen and can only be raised from the body in large folds. Its surface is dry, with scurf on the ears and cheeks and the hairs fall out. In advanced cases, anemia is present to a marked degree. The number of red corpuscles was usually under 4 millions per c.m.m.; in four cases it sank to lower than 2.8 millions and in one case even to 2.2 millions."

A. V. Eiselberg**observed after complete extirpation of the thyroid gland in young goats and lambs that the growth of the bony substance was arrested both in length and breadth and that development of the horns and hair was affected.

Osler, † in speaking of the cretins of certain districts of Europe, says, "The skin has certain characteristic changes, * * * it is thick, inelastic, and cold. It looks edematous, but does not pit on pressure. * * * The hair is thin, coarse, and dry, scanty on the body. The beard does not grow. The nails are brittle; the teeth carious."

Sajous,‡ speaking of cretins or infantile myxoedma, says, "The temperature of cretins is invariably subnormal; they always suffer from cold. The nutrition of all tissues is impaired; the brain remains undeveloped * * *. The skin is dry and thickened; the hair thin and coarse, sometimes absent; the nails are short, brittle, and striated."

It is a generally accepted physiological fact that the thyroid gland is an important factor in the growth and development of the

*Arch. klm. Cherurgie. Vol. XXIX, p. 254 (1883).

**Langenb. Arch. f. klin. Chir. Vol. XLIX, p. 207 (1895).

†Modern Medicine, Vol. VI, p. 449.

‡The Internal Secretions and the Principles of Medicine, p. 166.

young, and in the metabolism or repairs and maintenance of the body. Removal of the thyroid is accompanied by violent disturbances of the nutrition of certain parts of the body, and goiter, cancer, or any pathological condition which interferes with the proper functioning of the thyroid, brings about similar results. As the thyroid glands in these hairless pigs are obviously not normal and the condition of the pigs so closely resembles the conditions above described, we feel justified in assuming that the thyroid is not properly functioning and that the condition of hairlessness and general defectiveness is due directly to the disturbed thyroid function. Naturally the next step would be to examine the thyroid to ascertain whether or not its physiologically active constituent is lacking.

Baumann*** in 1895 showed that iodine was present in the thyroid. Hunt and Seidell,**** after a long and thorough investigation, say that their experiments "show conclusively that thyroid rich in iodine is more active than thyroid poor in iodine simply on account of the iodine; in other words, the iodine is the cause and not the result of the activity." This deduction is corroborated by the results of Roos,* Oswald,** Marine and Williams,† and Marine.‡

EXAMINATION OF THE THYROIDS

The thyroid glands were removed from the hairless pigs as soon as they were received and immediately prepared for examination. They were separated from adhering connective tissue and were then washed in a gentle stream of water for about fifteen minutes, gentle pressure with the fingers being used to remove as much blood as possible. After this treatment, the glands were placed between filter paper to remove adhering moisture and weighed. They were cut into fine shreds and dried and weighed. The iodine in the moisture-free residue was determined by the

***Zeitschrift f. physiol. chem. 1896, 21, p. 487.

****U. S. Public Health and Marine Hosp. Service. Hygienic Laboratory Bul. 47, p. 112.

*Zeitschrift f. physiol. chem. 1899, 28, p. 40.

**Arch. f. path. Anat. 1902, 169, p. 461.

†Archives of Internal Med. 1, p. 378 (1908).

‡Johns Hopkins Hosp. Bul. 18, p. 359 (1907). Jour. Inf. Dis. IV, p. 417 (1907).

Hunter method.* In a few instances the glands were kept for several weeks in a weak formalin solution.

Tables II and III give the results of these examinations and show—

1. That the thyroid glands from hairless pigs are abnormally large.

2. That the iodine content is very low in comparison with that of the normal gland.

3. That the degree of hairlessness varies inversely with the iodine content.

As it did not appear probable that the cause of the malady is due to a transmissible pathologic condition, and as it has been demonstrated by numerous investigators that the iodine content is the controlling factor of the physiological activity of the thyroid, we

TABLE II.—THYROID GLANDS OF AFFECTED PIGS

Lab. No.	Condition of pigs	Number of glands	Ave. weight of fresh glands (grams)	Dry matter in fresh glands (per cent)	Iodine in dessicated glands (per cent)	Iodine in dessicated glands (grams)
317	Fairly well haired	2	0.44	19.7	0.054	0.0000469
307	Slight hair, lived two days	2	1.45	16.1	.0152	.0000355
322	Fairly well haired	1	0.7	22.3	.015	.0000234
326	Partly haired out	4	1.53	18.85	.009	.0000259
319	” ” ”	1	0.64	17.35	.00864	.0000096
308	” ” ”	3	1.1	18.3	.0063	.0000127
335	” ” ”	2	0.61	18.75	.00525	.000006
320	Practically hairless	1	3.65	17.5	.0047	.00003
324	” ”	1	0.9	28.05	.00444	.0000112
323	” ”	2	1.52	15.6	.00425	.00001008
325	” ”	2	1.59	17.55	.00222	.0000062
336	Skin smooth and shiny, devoid of hair	8	0.61	19.7	.003	.0000036
338	Hairless	1	3.1	14.0	.00188	.00000816
337	”	2	2.6	17.15	.00135	.0000062
313	”	1	6.5	15.8	Trace	Trace
314	”	1	2.9	18.0	.0001	.00000052
315	”	1	1.17	17.7	.0001	.00000021
306	”	36	1.88	17.85	.0012	.00000403

*Jour. Biol. Chem., VII, 321 (1910).

TABLE III.—THYROID GLANDS OF UNAFFECTED ONE-DAY-OLD PIGS

Lab No.	Number of glands	Ave. weight of fresh glands (grams)	Dry matter in fresh glands (per cent)	Iodine in desiccated glands (per cent)	Iodine in desiccated glands (grams)
305	44	0.175	20.8	0.095	0.0000346
316	4	.208	20.9	.214	.000093
318	3	.23	18.4	.236	.0001
321	3	.27	24.2	.064	.0000418

next took up an investigation into the iodine requirement of the pregnant sow.

We have not had the opportunity of examining many thyroids from sows that have produced hairless pigs, but so far we have noted no indication of goiter. Many such sows observed in field work showed no external indication of enlarged thyroid and we assumed the glands to be of normal size. It is possible, however, that the iodine content of such a gland may be at the lowest point at which the functions of the thyroid can be carried on, and all iodine in food and water is required for the maternal gland, leaving nothing for the fetal thyroid. This will result in iodine starvation for the fetus, depressing the physiological activity of the gland and resulting in the peculiar arrested development characterizing this disease. We have noted that the iodine content of thyroids varies widely, and it is perfectly conceivable that a sow with a high iodine content might be able to produce normal pigs on the same feed that would produce hairless pigs in a sow with an iodine content at the lowest physiological limit.

F. Fenger* examined a great number of adult and fetal glands from animals killed at Chicago. He found that a large percentage of the fetal glands were abnormally large and had a very low iodine content, which he states is not the case with the adult glands, and from which he contended that "the demand for iodine in the rapid fetal metabolism and growth in certain instances may exceed the available supply furnished by the pregnant animal. This supply may be sufficient for the maintenance of the maternal metabolism,

*Jour. Biol. Chem., XIV, 397 (1913).

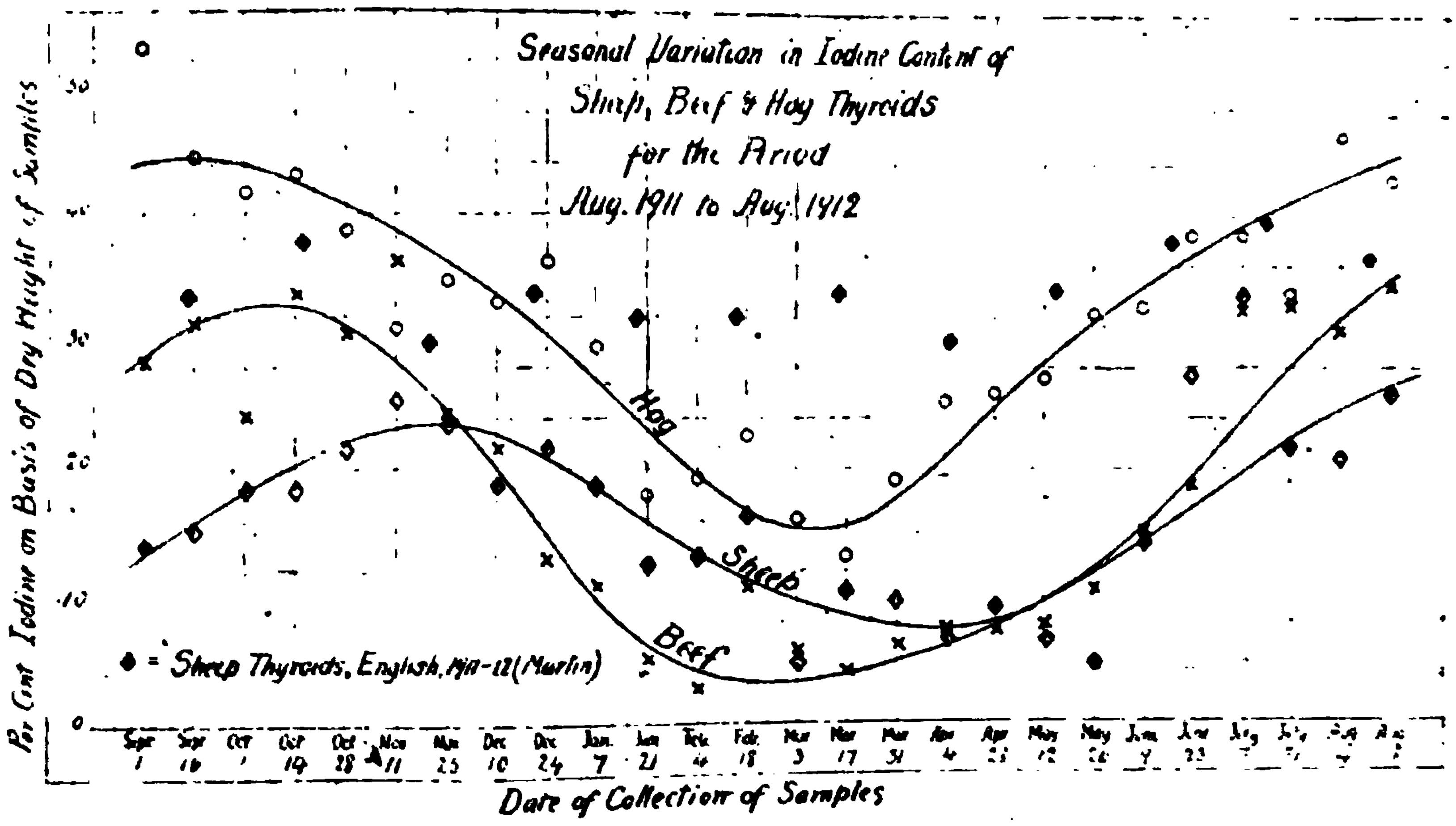

FIG. 6. Chart showing variations in iodine content of thyroid gland in sheep, beef, and hogs, at different seasons of the year. (From F. Fenger, Jour. Biol. Chem.)

leaving the adult thyroid normal, but not sufficient to prevent iodine starvation and enlargement of the fetal gland."

A. Seidell and F. Fenger* found that there was great seasonal variation in the iodine content of the thyroids of sheep, cattle, and hogs killed at Chicago. The iodine content was at a maximum in the summer, dropped rapidly during winter and spring, and rose to a maximum the following summer. This would indicate that the shortage of available iodine reaches an acute stage during the winter, probably due to the class of feed that they receive or the manner in which they are confined, which may cut them off from the source of some available iodine.

These results show that the iodine content of the thyroids of hogs is lowest from December to March, the period of the intra-uterine life of the spring litters. It has been pointed out that this malady is most prevalent with the early spring litters, which would indicate that this seasonal variation exerts a great influence upon the acuteness of the malady.

Various investigators have reported on the increase of iodine

*Jour. Biol. Chem., XIII, 517 (1912-13).

in the thyroid after feeding iodine. Hunt and Seidell* say that their results "show that when potassium iodide or iodoform is administered to dogs, the thyroids of the latter contain a greatly increased percentage of iodine and also are much more active physiologically."

Marine,** in reporting upon glandular hyperplasias of dogs' thyroids, says that "lack of iodine was the essential deficiency and iodine, when supplied, quickly overcame the needs."

Baumann† says, "The thyroid constantly contains an iodine substance, thyroiodine, or iodothyrin, which is present in the greatest quantity in old individuals, and in the smallest quantity in very young children. Iodothyrin is for the most part contained in the thyroid with an albumin and a globulin body, but it may appear in a free form. The normal thyroid is able to store up the extremely small amounts of iodine brought into the body in vegetable foods or in the drinking water and to convert it into the combination mentioned above. The internal administration of preparations of iodine, or the treatment of wounds with such, leads to a greater accumulation of iodine in the thyroid."

RESULTS OF FEEDING IODINE TO SOWS

To test these results with regard to sows, we fed ten sows two grains of potassium iodide daily during gestation, and ten other sows were used as checks on the first lot. One new-born pig from

TABLE IV.—IODINE CONTENT OF FETAL GLAND INCREASED BY FEEDING IODINE DURING GESTATION.

Lot No.	Number of fetal glands	Iodine fed daily during gestation (grains)	Iodine in fetal glands (per cent)
1	10	2	0.381
2	10	0	0.171

each of the twenty litters was killed and the iodine content of the thyroid determined. The results, shown in Table IV, would indicate that it is possible to raise the iodine content of the fetal gland by supplying sufficient iodine to the mother during gestation.

*Loc. cit.

**Jour. Inf. Dis., IV, p. 425 (1907).

†Loc. cit.

DETERMINATION OF IODINE IN FOOD-STUFFS

In the spring of 1915, a request was received from Dr. E. B. Forbes, of the Ohio Experiment Station, for samples of agricultural products from districts where goiter was known to be prevalent in man and animal, also from areas notably free from such trouble. He wished to make iodine determinations from these samples to ascertain if areas low in iodine could be located. We accordingly sent to Dr. Forbes a large amount of material from affected and unaffected districts. The results of this analysis of agricultural products did not indicate anything very definite. Iodine was found in only a very few of the samples collected, and in very small amounts. Iodine, as a constituent of plants, seems uncertain and inconstant. Samples of grain from spots fifty feet apart in the same field showed a distinct difference in iodine content.

As we have pointed out, the animals affected by goiter are to be found in definite areas and we expected to find food products of these areas deficient in iodine. It has been known for a long time that the eastern slope of the Rocky Mountains is a region particularly productive of goiter in man and animal. But analyses of foods and agricultural products did not demonstrate any general difference in the iodine content of material from any area, large or small. We can not state that areas are low in iodine and thus account for the low iodine content of the thyroids of the new-born of that area.

Analysis of the food of animals in affected districts will show in many cases that the iodine content is more than adequate. For instance, it was noted that wheat shorts constantly gave a high iodine content, and a series of samples from different points in the State gave the results shown in Table V. Such a percentage of iodine would indicate that if the sows were fed a wheat ration, the daily supply of iodine would be ample; that the amount of iodine in each ration of wheat would be larger than the total iodine of the thyroid. Yet a large number of the sows that produce hairless pigs are fed very largely on wheat and there is not sufficient iodine for both mother and young. These apparently contradictory facts deterred us from placing very much emphasis upon the iodine-shortage theory until substantiated by experimental iodine feeding.

There are two ways in which this *impasse* may be explained.

It may be that in the feed of the affected areas there is a substance which renders the iodine incapable of assimilation by the thyroid. Or, it may be that something peculiar to these areas so hastens the elimination of the iodine that the available supply is not sufficient. Whatever the explanation, we have the facts of an iodine starvation of the new-born in spite of the evidence that the food supply in many cases aparently has an abundance of iodine.

Possibly experimental feeding will reveal a ration that will increase the iodine content of the thyroid of the fetus to a degree that will enable it to function, but, as we have stated before, in affected areas no amount or variety of the ration has consistently prevented the occurrence of this malady.

TABLE V.—IODINE CONTENT OF WHEAT SHORTS

No.		Iodine content (per cent)
327	Shorts	0.0031
328	Shorts	.0036
329	Shorts	.0027
330	Bran and shorts	.002
331	Shorts	.003
332	Bran and shorts	.003
333	Bran and shorts	.0032
334	Bran and shorts	.0017

IODINE FEEEDING AS A PREVENTIVE OF HAIRLESS PIGS

In the fall of 1915, fifteen sows from an unaffected district were placed on an affected ranch, bred about December 1st, and kept there during the gestation period. They averaged about 225 pounds in weight and were of good quality, grade Durocs and Chester Whites. They were fed three to five pounds of mixed grain, red clover hay, and water q. s.—all products of the affected ranch.

Pen I, seven grade Durocs, was fed potassium iodide, 5 grains daily per sow, from December 15th to farrowing time.

Pen II, five Chester Whites, was fed sheep thyroid, dried at 100 degrees F. and pulverized, 5 grains daily per sow.

Pen III, five Chester Whites, was used as a check and fed only grain and hay.

The owner of the ranch added two sows to Pen I. These were pure-bred Durocs which in March and October, 1915, had each pro-

duced litters of hairless pigs. This pen produced an average of eight pigs to the sow—strong, vigorous animals that, with the exception of two, are still living and thriving.

In Pen II five Chester White grade sows produced thirty-two pigs, not so good as those in Pen I, but of fair quality. Six of these died in early spring.

Pen III was a check on the others. Only four of the sows farrowed in April and they produced eighteen pigs. These pigs were weak, wrinkled, low in vitality, and only five of the eighteen lived to maturity. They were not hairless but thin-haired and resembled the stronger pigs in a hairless litter. The difference in appearance between these pigs and those in Pen I was very striking, though the most careful observation could show no material difference between the sows in the two pens.

During the summer of 1916, the sows were run on pasture and one grain daily of potassium iodide supplied in grain feed. Eighteen normal litters were produced in the fall and nothing of importance was noted. The sows were bred early in January, 1917, and kept in two lots, potassium iodide being supplied to ten sows and a pen of eight sows used as a check. All the sows in both pens produced normal pigs with very little difference between the two pens as to vigor and vitality of the pigs. The experiment did not demonstrate anything the second winter and it was abandoned.

FURTHER EXPERIMENTS IN IODINE FEEDING

During the summer of 1916 a series of cooperative tests was undertaken with several farmers in affected districts. Potassium iodide in 5-grain daily doses was fed to twenty-eight sows on five ranches in the affected districts for the last four to five weeks of the gestation period. The sows that had already farrowed on those ranches had produced hairless pigs. Each sow produced normal pigs after receiving the potassium iodide. The experiments were not carried on under our direct supervision but there seems no doubt that a decided effect was produced by the potassium iodide.

In the fall of 1916, a more extended experiment with iodine feeding was inaugurated. Potassium iodide in 2 to 3-grain daily doses was distributed to a number of breeders, who fed it to the sows for about one hundred days. The results are given in Table VII.

TABLE VII.—RESULTS OF IODINE FEEDING.

Experiment	Iodine fed (gr.)	Days fed	Litters in 1917		Litters in 1916	
			Normal	Hairless	Normal	Hairless
1	2	70	6	0	0	6
2	3	75	7	0	0	8
3	3	100	4	0	4	2
4	2	100	14	0	30	10
5	2	100	2	0	4	2
6	2	100	10	*0	20	30
7	2	90	4	0	4	6
8	2	100	22	0	12	18
9	2	100	12	0	12	12
10	3	100	8	0	2	6
11	2	100	10	0	4	5
12	2	100	15	0	0	13
13	3	70	30	0	4	26
14	4	100	6	0	5	5
15	3	90	17	0	10	6
16	2	100	14	0	10	2
17	2	90	4	0	2	2
18	2	100	1	0	2	4
19	2	80	2	0	–	4
20	2	85	4	0	–	2
21	3	100	4	0	2	2
22	2	90	5	0	–	7
23	2	100	10	0	2	8

*One sow, not fed iodine, had hairless pigs.

The results from the iodine feeding have apparently been very favorable, but as there were no check experiments there is an element of error possible. In support of the above results it may be stated that these experiments were carried on at various points on the Yellowstone, Musselshell, and Missouri rivers, and in some cases far back from the river on some creek. In every case the breeders had been having trouble for some years, and in most cases this was the first year that there had been no hairless pigs. There have been as many hairless pigs as usual this year in the districts where the tests were carried on, so that we feel justified in concluding that the iodine was the agent that prevented hairlessness in the experimental pigs. Iodine feeding on a still larger scale will be carried on the coming winter.

TABLE VIII.—EXPERIMENT TO ESTABLISH DOSAGE OF POTASSIUM IODIDE.

Sample number	Dry weight of thyroid (grams)	Iodine in dry matter of thyroid (per cent)	Potassium iodide added to daily rations (grains)	Number of days fed
1	5.63	0.104	0	30
2	3.04	.170	0	30
3	5.69	.480	2	30
4	2.99	.420	2	30
5	1.80	.430	2	30
6	2.24	.424	2	30
7	3.535	.385	5	30
8	2.26	.496	5	30
9	3.06	.450	5	30

The exact amount of iodine necessary to accomplish the desired result probably varies with the requirements of each pregnant sow. The experiment on fat hogs, recorded in Table VIII, was an attempt to get an approximate dosage. These figures show that the maximum increase of iodine in the thyroid was obtained by feeding 2 grains of potassium daily and that a larger dosage is unnecessary No doubt the optimum dosage is much less than 2 grains but further experiments will be necessary to establish the minimum amount needed to increase the thyroid iodine to the physiological safety point.

SHEEP FEEDING EXPERIMENT

Only one experiment in supplying iodine to pregnant ewes was attempted. In 1916 a prominent stockman in eastern Montana lost all except about one hundred of the lambs from seven hundred ewes because of goiter, hairlessness, and weakness. In 1917, from early February, iodine was fed daily to two hundred yearling and one hundred aged ewes. These lambed in May and June and about 100 per cent of the lambs were saved. The lambs were notably strong and vigorous, in contrast to those of 1916, and not a single case of goiter occurred. However, the ewes in 1917 were kept in better quarters and had more exercise than in 1916 and also lambed in more favorable weather, factors which must be considered in estimating the value of iodine feeding.

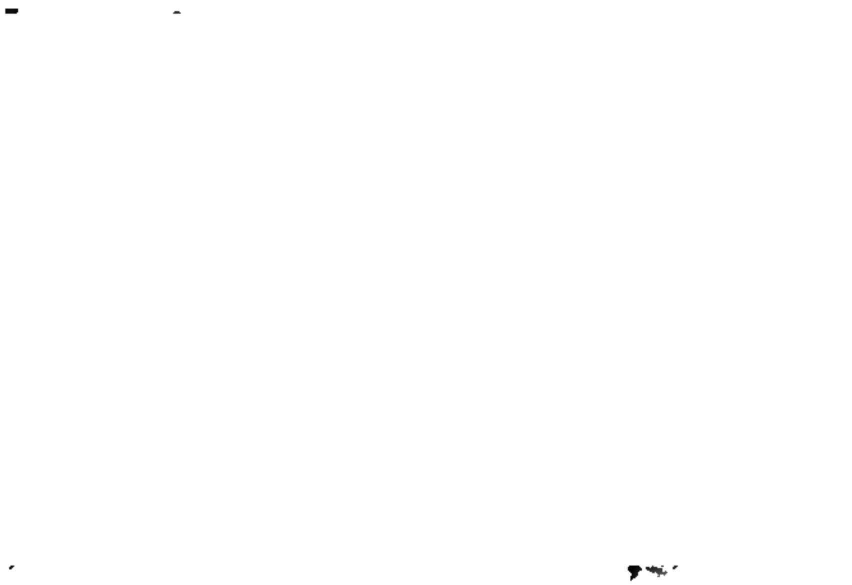

FIG. 7. New-born lamb, showing goiter and very thin wool.

FIG. 8. New-born calf, showing goiter. (Photograph by Dr. J. W. Kalkus, Pullman, Wash.)

FIG. 9. Weakness in new-born colt. The hairlessness and goiter are not as conspicuous in a foal. (Photograph by Dr. J. W. Kalkus.)

CATTLE FEEDING EXPERIMENT

Several small herds of cattle were started on experimental feeding in an attempt to prevent goiter in calves, but, owing to an extraordinary winter and spring, the experiments could not be carried through to calving time.

SUMMARY

1. Disturbance of the function of the thyroid gland appears to be the immediate cause of hairlessness in pigs, lambs, and calves, and of weakness in colts.

2. The enlarged thyroid glands are very deficient in iodine, which has been demonstrated to be the essential element for the proper functioning of the gland.

3. Iodine supplied to the female breeding stock during gestation is apparently effective as a preventive of goiter in the new-born.

4. We feel justified in advocating the feeding of iodine to pregnant domestic animals in sections of the Northwest where goiter is prevalent.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

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Date and Rate-of-Seeding Tests With Spring Grains Under Irrigation

BY

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Agronomist

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Date and Rate of Seeding Tests With Spring Grains Under Irrigation

The results reported in this bulletin are of tests conducted on the Montana Experiment Station farm at Bozeman. This is in the Gallatin Valley, in the south-central part of the State, at an altitude of 4,870 feet and is under irrigation.

The plots were one-fortieth acre in size, one rod by four rods.

All plantings were done with a carefully calibrated seed drill, which insured accuracy in the amount of seed sown.

Standard varieties of all crops were used in the tests. From 1907 to 1910 the Pringle's Champion wheat, a bearded variety of high milling quality, was used. For the years 1911 to 1914 the Stanley variety was used. The Swedish Select oat was used in all oat tests, and the New Zealand barley, a two-rowed variety of the Chevalier type, was used in the barley tests. Of peas, the White Wonder, a Canadian field variety, was used the first three years and the Alaska, a variety introduced by the garden pea contractors, was used in 1914, 1915, and 1916. Both varieties have medium-sized grains.

Careful determinations were made to find out the effects of the different times and different rates of planting on the yield of grain, the yield of straw, the weight per bushel of the grain, the length of the period from planting to maturity, the height of the crop, and the percentage of the crop lodged at harvesting time. The results are presented under these different headings.

Date of Seeding

In the date-of-seeding tests the plantings were not done on the exact day reported each year. This was impossible because of the variation in the time of the opening of spring. The plan followed was to plant on the first day that a seed-bed could be properly prepared each spring and then make plantings on the same day of the week for each of the seven weeks following. For comparison of the yields the average date for the entire period was determined and used. With wheat, oats, and barley the average date of the first planting was April 15 and the last planting, June 4. With

peas the first and last dates were April 18 and June 5. The experiments were carried on for seven years in the case of the first three crops and for six years with peas. Wheat, oats, and barley were planted at the rate of two bushels and peas at the rate of three bushels per acre.

YIELD OF GRAIN

Table I presents data showing the average yield of grain per acre from plantings made on the different dates. This shows clearly that early planting is to be recommended under irrigated conditions in the Gallatin Valley. With every crop the highest yields were from the early plantings. The yields grow smaller as the date of seeding becomes later.

To compare the returns from the first four plantings, April 15, 22, 29, and May 5, which may be considered as early plantings, and from the last four, May 13, 20, 27, and June 4, which are late plantings, the data have been averaged and the comparison is shown in Table II. The plantings of peas were from one to three days later in each case. The comparisons brought out in this table show substantial increase in the yield of grain from early plantings.

Aside from the better yields of grain produced, early planting has other advantages on the irrigated farm. Early planted grain

TABLE I.—YIELD OF GRAIN WHEN SEEDED ON DIFFERENT DATES
(Average bushels per acre)

Crop	Date of Seeding							
	Apr. 15	Apr. 22	Apr. 29	May 5	May 13	May 20	May 27	June 4
Spring wheat	65.94	60.65	52.52	53.38	49.81	44.66	35.16	31.11
Oats	99.59	95.81	99.20	90.02	85.08	68.60	77.43	71.88
Barley	73.98	71.72	72.98	69.29	70.11	66.18	61.81	60.82
Peas	44.65	43.78	40.11	36.89	37.28	41.60	37.00	33.67

TABLE II.—COMPARISON OF YIELDS OF GRAIN

Crop	Average bushels per acre		Increase in favor of early planting	
	First four plantings	Last four plantings	Bushels	Per cent
Spring wheat	58.12	40.19	17.93	44.6
Oats	96.16	80.75	15.41	19.1
Barley	71.99	64.48	7.51	11.7
Peas	41.36	37.39	3.97	10.6

may be irrigated early while the supply of water is abundant. The crop ripens in good time, thus escaping injury from early fall frosts. It may be threshed early and this affords opportunity to get the land fall-plowed, which in turn reduces the work the following spring so that the crops may again be planted in good season.

YIELD OF STRAW

Table III, giving the average amounts of straw produced from crops planted on different dates, shows that there is no significant difference in these amounts. The crops produce stem and leaves first. This is the manufacturing apparatus for converting the plant food taken from the air and soil into plant materials. It must be built up before the seed or grain can be matured. Evidently the amount produced does not vary materially on the average. With late planting the decrease is in the amount of grain produced. This relation between the amount of grain and straw produced is brought out in Table IV, which shows the average amount of straw for each pound of grain produced in all tests and the relation between grain and straw from the first four plantings and the last four plantings, considered as early and late planting groups. This shows clearly the relative loss in grain yield of late planted as compared with early planted crops. The late crops produce ample

TABLE III.—YIELD OF STRAW WHEN GRAIN IS SEEDED ON DIFFERENT DATES
(Average tons per acre)

Crop	Date of seeding							
	Apr. 15	Apr. 22	Apr. 29	May 5	May 13	May 20	May 27	June 4
Spring wheat	3.82	3.55	3.33	3.47	2.93	3.28	3.36	2.83
Oats	2.18	2.65	2.52	2.53	2.32	2.68	2.14	2.13
Barley	2.60	2.36	2.34	2.56	2.36	2.41	2.82	2.75
Peas	1.61	1.93	1.80	1.98	1.98	2.05	1.87	1.17

TABLE IV.—AVERAGE NUMBER OF POUNDS OF STRAW FOR EACH POUND OF GRAIN PRODUCED

Crop	All tests	First four plantings	Last four plantings
Spring wheat	2.25	2.04	2.57
Oats	1.69	1.59	1.80
Barley	1.54	1.43	1.67
Peas	1.53	1.48	1.58

straw. The loss is in the grain. It will cost practically as much to harvest the late planted, lighter yielding crops as the early planted ones which give the larger yield. The same amount of straw has to be handled.

QUALITY OF GRAIN.

As an index to the quality of grain harvested from plots planted on different dates, the weight per measured bushel was determined. The data are presented in Table V. In every case the grain from the early planted plots shows a higher weight per measured bushel than that from the late planted plots. This comparison is brought out in Table VI, which gives the average weight per bushel of the crops from the first four plantings and the last four plantings.

It will be noticed in Table V that the grain harvested from the latest plantings of spring wheat, oats, and barley was comparatively light. This was due to poor filling and in some seasons to shriveling from frost injury. Much of the grain harvested from plots planted the last week in May and the first week in June was so seriously injured by fall frosts as to be worthless for seed. Early spring planting is the remedy for the difficulty.

TABLE V.—QUALITY OF GRAIN SEEDED ON DIFFERENT DATES
(Average pounds per measured bushel)

Crop	Date of seeding							
	Apr. 15	Apr. 22	Apr. 29	May 5	May 13	May 20	May 27	June 4
Spring wheat	61.62	60.87	60.87	59.12	58.50	56.75	57.00	56.17
Oats	41.50	40.50	41.13	42.13	39.25	38.75	37.88	36.00
Barley	52.75	52.62	52.87	53.50	52.25	52.87	51.50	48.12
Peas	62.60	62.20	62.20	62.00	62.30	62.60	61.70	61.50

TABLE VI.—COMPARISON OF QUALITY OF GRAIN FROM DIFFERENT PLANTINGS
(Average weight per bushel)

Crop	All tests	First four plantings	Last four plantings
Spring wheat	58.89	60.62	57.10
Oats	39.64	41.32	37.94
Barley	52.06	52.94	51.19
Peas	62.14	62.25	62.02

LENGTH OF GROWING PERIOD

A record of the number of days from planting to maturity for crops planted at different times is shown in Table VII. It will be noted that the early planted grain utilizes a longer growing period than that planted late. This accounts, no doubt, for the increased grain production. There is sufficient good growing weather to permit the crops to mature fully and naturally if the planting is done as soon as conditions are favorable in the spring. If the date of planting is delayed the period of growth is shortened, since growth ceases with the coming of the frosts and cool weather of the early fall. In the higher valleys the season at the best is short for irrigated crops. It should be fully utilized by getting the planting done as early as conditions are favorable in the spring.

TABLE VII.—LENGTH OF GROWING PERIOD WHEN GRAIN IS SEEDED ON DIFFERENT DATES

(Average days from planting to maturity)

Crop	Date of seeding							
	Apr. 15	Apr. 22	Apr. 29	May 5	May 13	May 20	May 27	June 4
Spring wheat	139.17	134.33	132.57	133.43	127.00	125.85	123.06	118.83
Oats	135.14	129.85	124.28	126.28	125.13	124.14	117.16	111.00
Barley	134.43	130.71	125.00	124.71	122.43	118.86	112.83	110.33
Peas	131.00	124.30	119.30	113.30	116.00	108.00	108.80	101.80

HEIGHT OF THE CROP

The length of the straw was determined each year by measuring the height of the standing crop at harvest time. The data are given in Table VIII and show very little difference between crops planted at different times. The height of the crop differs from year to year but not in any manner that is generally significant.

TABLE VIII.—HEIGHT OF CROP WHEN SEEDED ON DIFFERENT DATES

(Average height in inches)

Crop	Date of seeding							
	Apr. 15	Apr. 22	Apr. 29	May 5	May 13	May 20	May 27	June 4
Spring wheat	50.67	47.83	49.57	49.71	48.28	50.71	50.00	49.28
Oats	47.28	48.00	48.00	47.43	47.83	47.33	48.67	45.33
Barley	41.43	42.14	40.57	42.43	43.00	42.00	41.17	39.50
Peas	47.60	48.00	46.80	47.80	46.20	47.80	47.60	47.40

This is in harmony with the straw yields as shown in Table III. The plant develops the stem and leaf regardless of the date of seeding. The reduction is in the grain yield.

LODGING OF CROP

Table IX shows the average percentage of the crop lodged. These data are given for wheat, oats, and barley only. The peas lie flat on the ground in regular growth.

Inspection of the table shows that lodging depends more on the seasonal condition than on the time of planting. In 1910, 95 per cent of the spring wheat planted on June 4 was lodged, while oats and barley showed no lodging that year. The wheat required 114 days to mature while oats and barley required only 99 days. The serious lodging was due to a storm after the other plantings had been harvested. In 1909, early planted grain lodged very little while the crops from the later plantings were down rather seriously. Over a period of years there is evidently little relation between date of planting and the lodging of the crop.

TABLE IX.—LODGING OF CROP WHEN SEEDED ON DIFFERENT DATES
(Average percentage)

Crop	Date of seeding							
	Apr. 15	Apr. 22	Apr. 29	May 5	May 13	May 20	May 27	June 4
Spring wheat	63.00	54.16	52.50	50.83	47.50	45.83	45.83	57.50
Oats	30.80	34.20	35.30	50.80	42.50	45.00	54.20	50.00
Barley	70.83	68.57	62.85	81.43	74.71	66.14	49.16	50.00

Rates of Seeding

Spring wheat, oats, barley, and peas were planted at the rate of 2, 4, 6, 8, 10, 12, 14, and 16 pecks of seed per acre each spring for eight years for the first three crops and seven years for the peas. The planting was done in one day each spring. The date varied with the spring but was during the last week in April or the first two weeks in May. The results of these tests will be presented under the same headings as the results of the date-of-seeding tests.

YIELD OF GRAIN

Table X shows the average yields of grain from different rates of seeding. From the point of view of yield the heavier rates of

seeding give the best returns. With spring wheat, seeding at the rate of 14 pecks—3½ bushels—per acre gave a slightly higher yield than the other rates. When the price of wheat is considered, however, this return would show very little more profit than that from the 8-peck seeding. The price of grain is usually higher in the spring than at harvesting time, so that the return from the 8-peck seeding is relatively good. On the average the returns from the heavy seeding are much better than those from light seeding. Evidently there is no profit in economizing with seed grain. The Experiment Station advises the use of 8 pecks of spring wheat seed per acre on irrigated land.

As with spring wheat, the heavier rates of seeding have given the best yields with oats, barley, and peas. Ten to 12 pecks of seed show the best average yield with oats. Ten pecks or 2½ bushels of seed are advised for this crop. With barley the highest average yield was from the 16-peck seeding. This is nearly 5 bushels higher than when 10 pecks were planted. However, the advantage is offset by the disadvantage from the more serious lodging of the thickly seeded crop, as shown in Table XV. The Experiment Station advises 8 to 10 pecks of seed per acre for irrigated barley.

The tests with peas show that at least 10 pecks of seed ought to be planted. The common practice is to plant 12 pecks and the results show that at least 10 pecks ought to be used. The Experiment Station recommends 10 to 12 pecks of medium-sized peas per acre for seeding under irrigation.

TABLE X.—YIELD OF GRAIN FROM DIFFERENT RATES OF SEEDING
(Average bushels per acre)

Crop	Rate of seeding—pecks per acre							
	2	4	6	8	10	12	14	16
Spring wheat	39.87	51.57	55.56	57.53	57.36	58.50	60.13	58.21
Oats	75.83	90.34	94.75	95.73	103.77	106.44	106.27	102.68
Barley	57.91	63.97	68.90	69.08	71.97	72.71	72.82	76.73
Peas	29.62	34.28	36.42	39.43	41.43	41.43	41.24	42.19

YIELD OF STRAW

Table XI shows the yield of straw from crops planted at different rates of seeding and indicates a slightly higher yield from heavy

seeding than from light seeding. This would be expected since the number of plants produced would increase as the amount of seed was greater. This would be partly offset by the size of the stems, which would tend to become smaller as the number increased.

TABLE XI.—YIELD OF STRAW FROM DIFFERENT RATES OF SEEDING
(Average tons per acre)

Crop	Rate of seeding—pecks per acre							
	2	4	6	8	10	12	14	16
Spring wheat	2.14	2.81	3.18	2.98	3.07	3.15	3.26	3.30
Oats	1.91	2.39	2.37	2.52	2.57	2.65	2.75	2.86
Barley	2.38	2.30	2.70	2.66	2.99	2.70	2.88	2.69
Peas	1.20	1.63	1.75	1.89	2.06	1.64	1.80	1.95

QUALITY OF GRAIN

To show the quality of grain harvested, the weight per measured bushel of the different crops was determined. The average is shown in Table XII. By this standard the quality of the grain with spring wheat, oats, and barley increases slightly as the rate of planting becomes higher. With peas the highest weight per measured bushel was from the lighter plantings. It is evident that the rates of planting which give the highest yields also give good quality of grain on the average.

TABLE XII.—QUALITY OF GRAIN FROM DIFFERENT RATES OF SEEDING
(Average pounds per measured bushel)

Crop	Rate of seeding—pecks per acre							
	2	4	6	8	10	12	14	16
Spring wheat	59.25	58.80	60.33	59.83	60.63	60.91	60.46	61.20
Oats	38.60	39.20	41.90	40.30	42.10	40.90	41.90	41.90
Barley	52.25	52.58	52.66	53.21	53.08	53.41	53.16	53.41
Peas	63.00	62.90	61.70	62.10	61.50	61.20	61.40	61.30

LENGTH OF GROWING PERIOD

The number of days from seeding to maturity of crops planted at different rates is given in Table XIII. This shows that as the amount of seed is increased the length of the growing period is lessened with all crops. This would warrant the recommendation that as the time of seeding becomes later the amount of seed should

be increased. This conclusion is borne out by work at the Kansas Experiment Station reported by Jardine.* He found that 2 pecks of seed produced as large yields as larger amounts when sown before the last week in September, but that 8 pecks of seed produced upwards of twice as much as 2 pecks when sown during the last two weeks of October. The proper amount of seed to use varies with the date of planting, but as a general rule the amount of seed should be increased as the date of planting gets later.

TABLE XIII.—LENGTH OF GROWING PERIOD WHEN GRAIN IS SEEDED AT DIFFERENT RATES
(Average days from planting to maturity)

Crop	Rate of seeding—pecks per acre							
	2	4	6	8	10	12	14	16
Spring wheat	129.2	128.5	128.2	126.1	125.9	124.4	123.7	124.4
Oats	122.1	119.8	119.7	118.8	119.3	119.4	120.0	118.7
Barley	125.1	124.2	123.1	121.9	119.2	118.1	118.0	118.5
Peas	124.0	125.0	125.0	125.0	125.0	125.0	124.0	124.0

HEIGHT OF THE CROP

Table XIV shows the average length of the straw as measured at the time the crop was ripe. Very little variation is noted in the height of the spring wheat, oat, or barley crop grown from varying amounts of seed. In the case of peas the length of the straw increases as the amount of seed is increased. This increase varied with the different years but the general tendency was for the length of straw to be greater as the amount of seed was greater.

TABLE XIV.—HEIGHT OF CROP WHEN SEEDED AT DIFFERENT RATES
(Average height in inches)

Crop	Rate of seeding—pecks per acre							
	2	4	6	8	10	12	14	16
Spring wheat	49.75	49.75	49.37	49.12	50.00	49.75	48.87	48.62
Oats	48.14	48.71	48.85	48.71	48.00	48.00	49.14	46.71
Barley	42.50	40.87	40.87	40.62	41.25	42.37	43.00	42.00
Peas	45.00	46.70	47.30	49.30	48.70	50.50	51.20	50.50

*Effect of Rate and Date of Sowing on Yield of Winter Wheat. Jour. Am. Society of Agronomy, v. 8, no. 3, p. 163.

LODGING OF THE CROP

Table XV shows the average percentage of the crops lodged with the different rates of seeding. It will be seen that there is a very definite relation between the amount of seed planted and the lodging of the crop. As the rate of seeding increases the tendency of the crop to lodge becomes more general. This is to be expected. Higher rates of seeding mean more plants to a given area. This condition forces the production of smaller stemmed plants and plants imperfectly developed at the base. The crowding shuts out the light, which would make for the production of thin stems at the base of the plants.

TABLE XV.—LODGING OF CROP WHEN SEEDED AT DIFFERENT RATES
(Average percentage)

Crop	Rate of seeding—pecks per acre							
	2	4	6	8	10	12	14	16
Spring wheat	25.00	25.00	25.62	28.75	28.75	31.00	32.25	34.37
Oats	2.85	13.50	15.00	13.50	15.70	17.10	26.70	35.70
Barley	40.00	51.25	65.00	60.62	63.50	62.87	66.62	62.25

Summary

DATE OF SEEDING

The largest yield of grain was harvested from the earliest plantings. The yields from plantings made April 15, 22, 29, and May 5 in comparison with yields from plantings made May 13, 20, 27, and June 4 showed an average increase in favor of early planting of 44.6 per cent with spring wheat, 19.1 per cent with oats, 11.7 per cent with barley, and 10.6 per cent with peas.

There was small difference in the total amount of straw produced from plantings made at different times. Since the yield of grain was smaller from the late plantings, the number of pounds of straw for each pound of grain produced was higher with the grain planted late than with that planted early.

Grain from early plantings was of better quality, as shown by a higher average weight per measured bushel, than grain from later plantings.

Early planted grain utilized a longer growing season than late planted grain. This was doubtless due to the fact that the growth

from the late plantings was terminated by fall frosts and cool weather.

There was no significant difference in the length of straw of crops planted at different times. This is in harmony with the essentially uniform yields of straw.

The lodging of the crop evidently depends more on the season than on the date of planting.

RATE OF SEEDING

In rate-of-seeding tests the highest yield of spring wheat was from 14-peck seeding. This was 2.6 bushels higher than from 8-peck seeding. Considering the higher price of grain in the spring, the most profitable yield was from 8-peck seeding. With oats, 10 to 12 pecks of seed per acre gave the highest yield. The largest yield of barley was from seeding at the rate of 16 pecks per acre. When the lodging and other conditions are considered, the most profitable yields were derived from 8 to 10 pecks of seed. With peas, 10 to 12 pecks of seed gave the best yields.

The yields of straw increased as the rate of seeding increased.

The quality of the grain, as shown by the weight per measured bushel, was slightly higher from the heavier planting of spring wheat, oats, and barley. The reverse was true with peas.

As the rate of seeding increased, the length of the period from planting to maturity lessened. This would warrant the recommendation to increase the amount of seed used as the date of planting is delayed in the spring.

With spring wheat, oats, and barley there appears to be no relation between the length of the straw and the amount of seed planted. With peas the length of the straw increases as the amount of seed is increased.

The higher the rate of seeding the greater the tendency of the crop to lodge.

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Crown-Gall Injury in the Orchard

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Crown-Gall Injury in the Orchard

Crown gall is a disease attacking such a large number of host plants that much work will be required to determine the extent of injury to each. It will be necessary to consider the losses from two standpoints—the percentage of host plants attacked, and the injury done to each host after it is attacked. It is evident from a review of the work already done that some kinds of plants are rarely attacked and others frequently; and that when attacked some are very seriously damaged while those of other species remain practically normal except for the presence of the gall itself. Unfortunately this state of affairs is not sufficiently recognized and there has been a tendency to assume that because crown gall is very destructive to one host it is equally so to others. This is particularly true of fruit trees. Early work established the fact that certain stone fruits when attacked by crown gall seldom make good orchard trees, and this has evidently influenced many writers to make statements applying this fact to orchard trees in general, regardless of species.

THE DISEASE

Until a few years ago it was difficult to define crown gall sharply from some other malformations. The cause was unknown, notwithstanding the fact that a great deal of work had been done on the subject. Since the publication of a paper by Smith and Townsend (15) in 1907, demonstrating that the disease is produced by a bacterial organism (*Bacterium tumefaciens* Sm. and Town.), we class as crown gall all abnormal growths in plants that are caused by that organism.

In general these abnormalities are of two kinds—true galls on roots, crowns, or stems, and "hairy root," a condition in which unusual tufts of fine roots are produced, often at the expense of the main anchor roots. Confusion has arisen because the callus that forms in grafting and budding has a superficial resemblance to crown gall in early stages, and because unfavorable conditions of temperature and moisture may stimulate the growth of masses of fine roots much resembling hairy root; but the final distinction should be made henceforth on the causative agent, not on the symptoms alone. Unfortunately we have not yet found a method of mak-

ing rapid examinations of nursery stock for the bacterial organism and can profitably make such examinations only in rare cases.

EFFECT ON DIFFERENT HOSTS

The crown-gall organism appears able to attack a wider range of host plants than any other plant parasite. Smith, Brown and Townsend (16) have produced typical symptoms by inoculating many different species of plants. Doubtless further work along this line would show that many others are susceptible also, as only a small proportion of those inoculated under the most favorable conditions proved immune. Horticulturists have reported the disease more or less serious under field conditions on nearly all fruit trees, shrubs, and vines, and some damage is being done to vegetables and field crops. Some shade trees are also badly galled.

The authors of this bulletin have made a close study of the injury done to apple trees by the disease, but as injury to a host plant is a relative matter we will review briefly for comparison the reports of other workers on injury to different fruits. This will also show the danger in making general statements concerning the injury done without specifying the host. Only a few of the many references will be cited, but these all appear to be based on actual field observations by their authors.

INJURY TO ALMOND ORCHARDS

Toumey (21) reported that crown gall was highly destructive to almond trees, due in part to the fact that the large galls die and slough off and a destructive rot sets in at the wounds thus made. An orchard of forty acres of large trees of bearing age was so badly damaged that the trees were cut down and burned.

INJURY TO PEACH ORCHARDS

Toumey (20) has shown that peach and related trees are very seriously affected. If bearing trees have large galls on one side of the crown, the effect is shown in the condition of the tops on that side. Badly diseased trees may live for some time but seldom bear.

Bailey (2) states in reference to the peach that "trees thus affected stop growing and assume a yellowish and sickly look."

Selby (12) expressed his belief that peach trees affected with crown gall when transplanted will never come to profitable bearing. This belief was based partly, but not entirely, on personal

observation of an orchard of two hundred trees affected when set. This orchard was grubbed out as worthless when the trees had been set seven years, while nearby orchards of healthy trees were in profitable bearing.

Taft (19) states that peach trees affected with gall at the crown will make an unsatisfactory growth even if they live.

INJURY TO PLUM ORCHARDS

Paddock (11) published a figure of a six-year-old plum tree of which he says, "This tree was undoubtedly attacked in the nursery, and the continued growth of the gall so interfered with its nutrition that it was able to make but a feeble growth and was nearly dead when dug."

C. O. Smith (14), discussing the effects on stone fruits in California, says, "There are many almond, peach and prune orchards that today are unprofitable because of this disease."

INJURY TO VINEYARDS

Hedgcock (7) in extensive field observations on many varieties of grape-vine, especially in the Southwest, found that in general this vine suffers severely as a result of crown-gall infection. Often the vines die back to the site of the gall, due in part to decay setting in at that point, and in part to loss of moisture through the wounds make by cracking and sloughing of the gall tissue. While the vines are seldom killed outright by the disease, they are stunted, deformed, and made so unprofitable that many thousands are removed. Some varieties, however, resist the disease much better than others.

INJURY TO BLACKBERRY PLANTINGS

Lawrence (10) and others have reported a serious form of crown gall on the canes of blackberry that causes them to split open. It may even attack the petioles and veins of the leaves. It is especially destructive on certain varieties.

Jarvis (9) states that as a result of galls on the crowns the canes become sickly in appearance and frequently break off.

INJURY TO RASPBERRY PLANTINGS

Lawrence (10) has observed that crown gall damages the raspberry even more than the blackberry.

Selby (13) states that crown gall is one of the most destructive

diseases of raspberry, resulting in the destruction of bearing canes. He leaves a little doubt, however, whether his statements refer entirely to crown gall or in part to galls caused by "eel-worms."

According to Barss (3) considerable damage results from crown gall on raspberries, blackberries, and loganberries.

From a study of the literature it is quite clear that plant pathologists and horticulturists all over the country are almost unanimous in their testimony that crown gall, under field conditions, does serious damage to stone fruits, grapes, blackberries, and raspberries. Our own field observations on the peach, blackberry, and raspberry coincide with these reports. We have had little opportunity to study the disease on almond and grape.

INJURY TO APPLE ORCHARDS

When we turn to a consideration of the effects of crown gall on apple trees standing in the orchard, the evidence of different workers is rather conflicting.

Hedgcock (8) brings out this fact clearly and the reader is referred to his bulletin for a review of the work up to 1910. Hedgcock himself, in the same bulletin, reports some general field observations and a somewhat detailed study of crown gall in four experimental orchards in which diseased and healthy trees had been set. The records on the development of the trees and of the disease were taken at intervals varying from one to six years. The experiments were seriously marred by a fire that swept through three of the orchards, but some valuable data were obtained. A little larger percentage of the crown-galled than of the healthy trees died in the orchards during the first two years after planting. On the other hand, in comparison with the healthy trees, a little smaller percentage of those having the hairy-root form of the disease died. In growth and general vigor after six years practically no difference between healthy and diseased trees could be observed. Careful measurements, however, showed that the diseased trees were a little smaller in diameter. Very little attention appears to have been given to the development of the root system.

More recently Back (1) has reported on orchard experiments begun by the Crop Pest Commission of Virginia in 1906. It is stated that, owing to changes in personnel, important notes were lost or were never taken, but some notes were published, together

wth an extensive series of photographs of the roots of crown-galled and healthy trees. One series was taken at the time the trees were set and another of a portion of them after they had grown in the orchard for six seasons. Especial attention was given to the condition of the root systems, of which the author says, "It will be seen that no good root systems have developed during the past six years on the dug trees." This statement is fully justified by the illustrations published.

Many nurserymen have contended very stubbornly that crown gall is not infectious and that it is to be looked upon as a blemish and not a disease at all—merely an excessive development of callous tissue at the unions made in grafting and budding, particularly budding, and that it does no permanent injury to the trees. Unfortunately support of these contentions has been given by Hedgcock (5), who from his studies submitted the following conclusions:

"Soft crown-gall is rare, and may be related to the gall of the stone fruits. It may be slightly contagious. Hard crown-gall is related to callous formation, of which it is probably a pathological form. It is favored by stiff, heavy soils. The hairy root is a very peculiar disease, if it can be called one, with some physiological phenomena which separate it from true diseases. Cuttings from hairy-root seedlings root very much more readily and much better than from healthy ones. It is often easy to grow trees from such cuttings, but almost impossible to grow them from normal cuttings."

From the published work on crown gall and from our own experience with this disease we are led to believe that the conflicting opinions as to the damage done to apple trees when attacked by crown gall are due to the following facts and perhaps others:

(1) From known injury to certain kinds of fruits it has been inferred that apple trees would be similarly injured.

(2) From the unsightly appearance of the malformations, combined with knowledge, recently acquired, that the disease is caused by a bacterial organism, an inference has been drawn that serious damage would result.

(3) Under orchard conditions some have not observed closely enough the damage that was actually being done.

(4) Some have attributed to crown gall damage that was being done by other agencies, as nematodes, wood-rot fungi, unfavorable soil, etc.

(5) From the fact that some apple trees known to be affected

have made a good growth for a few years after being set in the orchard, it has been inferred that no appreciable damage would result even after they came into bearing.

(6) Not enough consideration has been given to the location, size, and character of the galls, nor to the condition of the root system aside from the galls.

(7) A poor development of the root system as a result of crown gall has often escaped notice.

(8) In different soils crown-galled trees behave differently.

EXPERIMENTAL WORK BY THIS STATION

During a time when shipments of nursery stock into Montana were very heavy, the controversy with the nurserymen as to the ultimate effect of crown gall upon apple orchards became so strong that it was decided to set out an orchard of affected and healthy trees and study, year by year, the effect of the disease upon the trees. This orchard was set out upon the horticultural substation grounds near Corvallis in the Bitter Root Valley in western Montana.

The following data will be of value in showing the conditions under which the experiment was carried out.

Source of stock—A prominent nursery in the Middle West.

Date of setting—May 20, 1910.

Varieties—Anisim, Hibernal, Hyslop (crab), Longfield, Northwestern (Greening), Oldenburg (Duchess), Patten, Wealthy, Whitney (crab), and Wolf River—ten in all.

Number—Twelve healthy trees and twelve diseased ones of each variety—a total of 240.

Age—Two years, i. e., grown from root grafts made in 1908.

Condition—All vigorous and thrifty.

Plan of planting—Trees set in rows, eight feet apart each way. The diseased trees were in a solid block, ten by twelve rows, and the healthy ones in a similar block adjoining it on the north (fig. 1).

Soil—A light sandy loam, underlaid at a depth varying from sixteen to thirty inches with a lime and clay hard pan. The land has a gentle slope to the south.

Detailed notes were taken on each tree before it was set in the orchard. Every diseased tree had at least one gall on the crown.

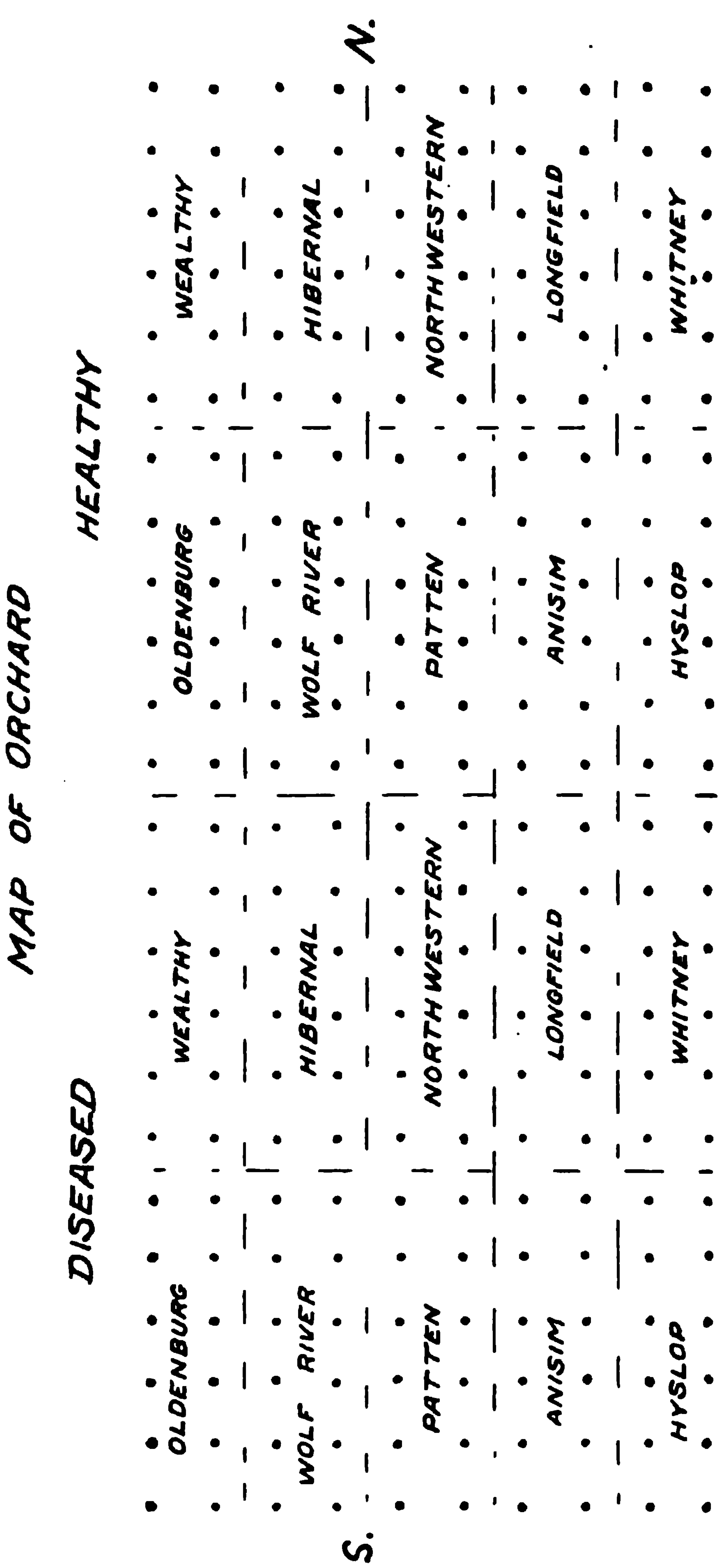

FIG. 1. Map of crown-gall orchard in the Bitter Root Valley, showing varieties, and relation of diseased to healthy trees.

most of them had two or three, and a few had four. These varied in size from one to two and one-half inches. As a rule they extended from one-third to one-half of the way around the crown, but a few nearly or quite encircled it. Nearly all had a few small galls on the lateral roots. Nearly all had more or less of the hairy-root form of the disease, which on some was very abundant. In other words, these trees all showed the disease in a well-developed condition. Practically all forms of the disease were well represented excepting the aerial type. In one respect the trees were not quite representative of crown-gall stock as it is received by orchardists when no restrictions are placed upon the sale of such stock, in that all trees that had developed hairy root at the expense of good, strong anchor roots had been culled out at the nursery. There was not a single tree of the kind we have often seen in commercial shipments in which the whole root system consists of a mass of hairy roots with no large, strong ones. Every tree in this lot had good, strong roots.

The trees were carefully set and were well cared for by the superintendent of the substation. Only a very small proportion of them died as a result of transplanting from the nursery.

In September, 1912, notes were taken on all the trees. In general, the growth of both the healthy and the diseased trees had been very good; indeed there was no apparent difference between the corresponding varieties in the two blocks in the matter of tops and trunks. Half of the trees were then dug up and the roots examined. For this purpose every other row diagonally was taken. At this time a marked difference was apparent in the root systems of the healthy and the diseased trees, those of the former being in almost every case stronger. Reference to the original notes showed that none of the galls excepting a few of the smaller, softer ones had disappeared but that most of them had enlarged considerably.

During the summer of 1915 blight was severe in the Bitter Root Valley and these young, vigorous trees suffered considerable injury. Some were killed outright, while others were so badly injured that practically the whole top had to be removed. In the spring of 1916 all the killed and badly blighted trees were pulled out and the difference between the root systems of the diseased and the healthy trees was most apparent. A horse was used for this work and in most cases he was unable to remove the healthy

trees with a single pull but had to pull repeatedly this way and that to break off the roots. On the other hand, very little trouble was experienced with the diseased trees. With a few exceptions the horse pulled them out at a single attempt, sometimes with very little effort indeed.

In November, 1917, final notes were taken and the last of the trees were removed as it was necessary to use the land for other experimental work. At this time, after a growth of eight seasons, few of the galls had disappeared entirely and most of them were still growing. Some were several inches in diameter. In some cases there was a general enlargement of the diseased crowns to more than twice the circumference of those of any of the healthy trees. Very few new galls, however, had been formed either on the crowns or on the roots. The hairy-root condition was very little in evidence and in most cases it could scarcely be found. So far as we could tell none of the trees had died as a direct result of crown gall, though the havoc wrought by blight so complicated matters that we can not say positively that crown gall had killed none. No very great difference was apparent between the tops of the diseased and the healthy trees, though a good observer could notice that the healthy ones had made a little better growth. The root systems of the diseased trees, however, were very inferior. The ac-

Table showing circumference in inches of healthy and crown-galled trees after growing in the orchard for eight seasons.

Variety	Healthy				Crown-galled			
	Number of trees	Largest	Smallest	Average	Number of trees	Largest	Smallest	Average
Anisim	5	14.25	13.00	13.60	4	12.75	10.75	11.75
Hibernal	4	16.00	15.00	15.56	6	11.25	10.00	10.67
Hyslop*	0	....	....	....	0	....	....	... .
Longfield	3	13.75	12.25	13.00	5	12.75	8.75	11.00
Oldenburg	5	13.50	11.75	12.60	6	12.00	10.00	11.00
Northwestern	6	15.75	11.75	13.13	4	14.50	12.75	13.44
Patten	5	12.50	10.75	11.60	3	11.25	8.50	10.00
Wealthy	2	12.50	12.00	12.25	3	13.00	12.00	12.42
Whitney*	0	....	....	....	0	....	....	.... ..
Wolf River	6	16.50	10.00	13.21	4	13.75	11.25	12.70
Entire block	36	16.50	10.00	13.12	35	14.50	8.50	11.54

*All trees of these two varieties were removed prior to 1917.

companying table shows the number of trees of each variety that remained to be dug out at this time and the relative circumferences of the trunks twelve inches above the surface of the ground.

From this table it may be seen that with the exception of Northwestern Greening and Wealthy the dwarfing effect of the crown gall was quite apparent. In Northwestern Greening the tops of the diseased trees were fully as good as those of the healthy ones. The Wealthy trees were so reduced in number by blight that a fair comparison was hardly possible. In no case was a tree so markedly dwarfed as one sometimes finds, apparently as a result of crown gall, in a bearing orchard. The reduction in size, however, is much more pronounced than that reported by Hedgcock (8) for a similar experiment carried out in Missouri. The average reduction in **circumference** in the Montana experiment was 1.58 inches. The average reduction in **diameter** in the Missouri experiment was 0.29 inch. We preferred to measure circumferences rather than diameters because the irregularities in trunks would have made measurements of the diameter rather uncertain.

The most striking thing brought out by this experiment is the greatly disturbed balance between the tops and the roots of the affected trees. Doubtless this would have been still greater had not those with no strong anchor roots been culled out and discarded before shipment from the nursery. Whether or not the weakened root systems would have resulted in more serious injury to the tops or the crop after the trees came into heavy bearing can only be surmised. If not, it is of no significance unless the trees have a greater tendency to loosen in the ground under the influence of the high winds. In the sheltered location of this orchard there was no such tendency.

All things considered, it is safe to say that the increased value of the healthy trees over the galled ones at the time they were removed was much more than the original cost of the nursery stock.

INFLUENCE OF CHARACTER OF DISEASE ON ULTIMATE EFFECT UPON THE APPLE TREE

Under the name crown gall we now include all abnormal growths caused by the bacterial organism, *Bacterium tumefaciens*. This excludes all gall formations due to nematodes, woolly aphis or other insects, or any other form of life excepting the organism

just named. The disease, however, shows several manifestations.

Following the usage of certain nurserymen, Stewart, Rolfs and Hall (18) first published the term "hairy root" to describe that form of the disease in which the chief manifestation is an abnormal mass of fibrous roots growing in dense clusters. They regarded it as a distinct disease, though with our present knowledge we can recog-

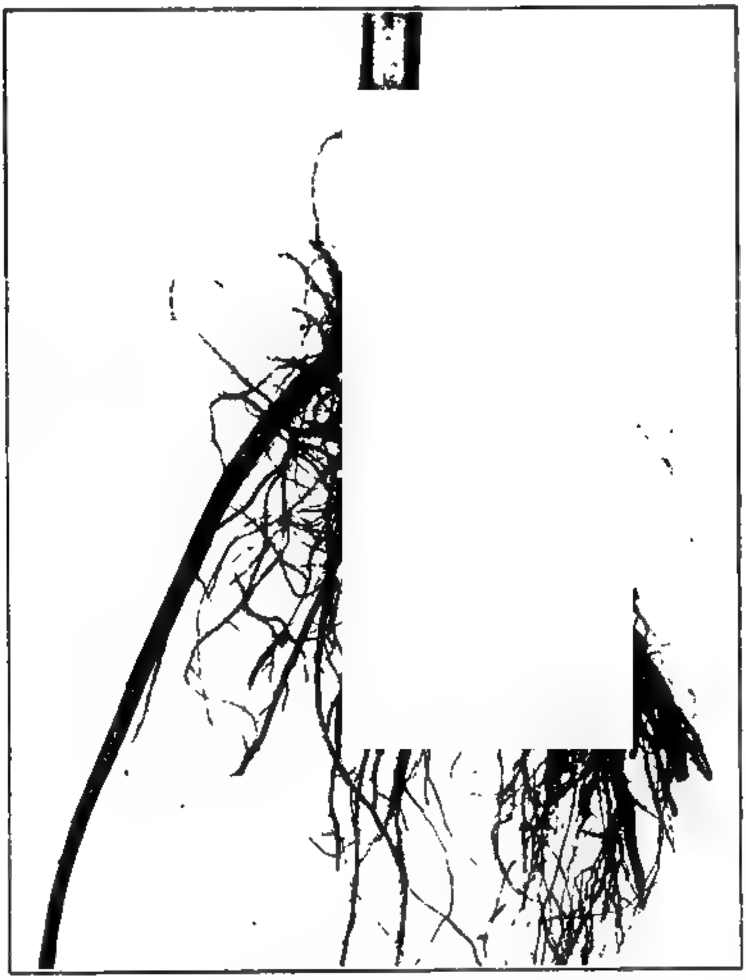

FIG. 2. Hairy-root form of crown-gall, of moderate severity, showing poor development of strong anchor roots.

FIG. 3. Mild case of hairy-root on tree with many strong roots.

nize in their Plate XXIII flat galls where the tufts of roots attach to the crown.

Hedgcock (4) accepted this view that crown gall and hairy-root are two distinct diseases. He classified crown gall as "hard" and "soft," the former more permanent and the latter more likely to rot off. In a later paper (5) he subdivided hairy-root into several different kinds.

An aerial development on trunks and branches has been described by Hedgcock (6) and others.

Smith (17) and his assistants have furnished convincing evidence that the so-called hard and soft forms of crown gall and the hairy root are all caused by the same organism and must be regarded as different manifestations of one disease. They submit the hypothesis that the kind of tissues stimulated by the organism to abnormal growth will determine whether the resulting gall will be hard or soft.

FIG. 4. Cross-sections through three crown-galls: (a) gall extends only one-third around root; (b) gall extends more than half way around root; (c) gall entirely girdles root. The black dot in each case marks the original center or pith of the root. (Natural size.)

In the apple the degree to which the tree will be injured when attacked by crown gall will be determined partly by its environment after being planted—especially the character of the soil—but also by the character of the disease itself. If the hairy-root form is developed at a sacrifice of large anchor roots (fig. 2), a poorly rooted tree will be the result. If, on the other hand, some tufts of hairy root are developed on an otherwise good root system (fig. 3), this is relatively unimportant. If there are large galls on the crown they are of more importance than if on lateral roots, especially the smaller ones. Galls that are attached by a narrow neck, like that shown in figures 4a and 5, or narrower, are much less injurious than those that extend nearly or quite around the crown or root (figs. 4b, 4c, and 6).

The principal damage done by the galls seems to be an interference with the normal conduction of water and food, and a mechan-

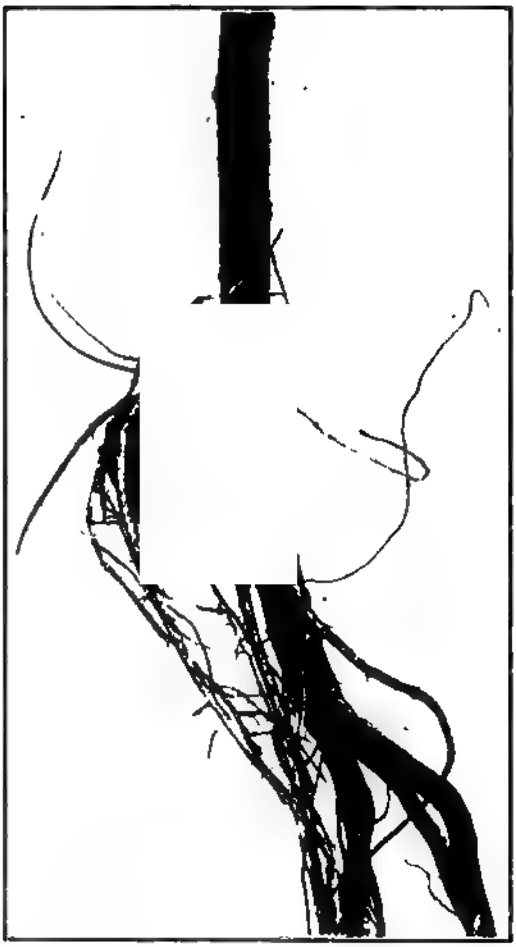

FIG. 5. Crown-gall with relatively narrow attachment to crown.

ical weakening of the crown or root at the point of attachment. When pulling out affected trees with a horse, it was not unusual for them to break across through a badly galled crown, the break usually taking place through the upper portion of the gall.

In addition to the experimental work reported in this bulletin, we have occasionally observed very much dwarfed apple trees in bearing orchards much older than the one at the horticultural substation. When dug up and examined, certain of them showed an

FIG. 6. Crown-gall nearly girdling the crown.

exaggerated development of crown gall with a reduced root system and no other tangible cause of the dwarfing. We naturally assign crown gall as the cause of the dwarfing.

CONCLUSIONS

(1) It is not safe to assume from damage done to one host that like damage will be done to another host.

(2) Apple trees attacked by crown gall are much less injured by it than are the almond, peach, plum, grape, blackberry, or raspberry.

(3) Some varieties of apple are more injured by the disease than others.

(4) Apple trees affected with crown gall and planted in the orchard will seldom make as good trees as those unaffected. The damage done will vary from practically nothing up to a condition of serious dwarfing.

(5) The dwarfing is much greater in the roots than in the parts above ground, but as the roots are not visible this fact has been generally overlooked.

(6) The ultimate injury will be affected by at least two factors—environmental conditions and character or type of the disease.

(7) Hairy root in so far as it develops at the expense of strong anchor roots is very important. This form of the disease on an otherwise well-developed root system is much less important.

(8) Galls on the crown are more serious than those on the lateral roots, especially on the smaller ones.

(9) Galls damage the trees by interfering with food conduction, by mechanically weakening the crown and roots, and by paving the way for other diseases.

(10) As a general proposition it would be better for an orchardist to pay the regular price for healthy stock than to plant crown-galled stock if he could get it free.

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UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION
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The Cost of Growing Wheat on Typical Non-Irrigated Areas in Montana

BY
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SUMMARY

Studies were conducted on typical non-irrigated areas in the Gallatin Valley and the Judith Basin in 1914 and 1915 to determine the cost of growing wheat in these areas, and to gain information on the relation of the wheat enterprise to the system of farm management that has developed in these regions.

Wheat is by far the most important crop grown in each of the areas studied. In the Judith Basin the acreage in wheat is over three times as great as that of all other crops combined. The preponderance of wheat area is almost as great in the Gallatin Valley.

Farms in these regions are lightly stocked. Crops that might be raised for pasture and forage do not appear to be well adapted to dry land conditions. They are unable to compete with the wheat crop for the use of land and labor.

Farms in the Gallatin area have been under cultivation for an average period of 30.9 years. The Judith Basin is a newer area. The farms there have been under cultivation for only 8.8 years. In this newer Judith Basin area considerably less labor is necessary in growing a crop of wheat than is the case in the Gallatin. The greater amount of work necessary in the older area is an indication that weeds are becoming a serious pest and that the soil is suffering in physical condition from the running down of the organic content. Continuous wheat cropping must some day give way to a system that is better balanced and more permanent.

The summer fallow method is followed rather closely in the Gallatin Valley. With this method the land is in wheat every other year and in summer fallow during the alternate years. A common cropping practice in the Judith Basin is that wherein two crops of wheat follow summer fallow, the second being "stubbled in." Stubbled-in wheat yielded on the average 23.4 bushels per acre, and wheat on summer fallow 36.5 bushels. This difference in yield at present prices would more than pay the cost of growing an entire acre of wheat. If, however, land is abundant and by stubbling in a portion of the crop growers are able to increase considerably the total acreage grown, the practice is justified even though the yields are considerably less.

Eighty-seven per cent of the farmers in the Judith Basin burn all or a part of their straw, as do 73 per cent of the Gallatin Valley

farmers. Burning straw in these areas is a practice that should be strongly condemned. Some method should be found for getting this organic material back into the soil. Some farmers follow the practice of scattering straw on the wheat fields in the fall as a top dressing. This straw has a tendency to protect the wheat crop through the winter and also to help retain moisture. After the crop is removed the straw has become so far decomposed that it may be plowed under and incorporated with the soil without any bad effects on the following crop.

Plowing to a depth of six or more inches seems to result in larger yields in both the Gallatin Valley and the Judith Basin than is the case where the land is plowed less deeply.

One of the important items of cost in growing wheat is the charge for the use of land. Six per cent of the market value of the land has been charged annually to cover this cost. This resulted in a rental charge of $6.56 per acre in the Judith Basin and $7.86 in the Gallatin Valley. Farmers who cash-rented paid $7.00 per acre in the Judith Basin and $7.18 per acre in the Gallatin Valley.

To grow an acre of wheat in the Gallatin Valley required 8.17 hours of man labor. In the Judith Basin 6.46 hours were needed. Hauling the wheat from an acre of ground from separator to granary required 1.17 hours in the Gallatin and 0.73 hour in the Judith Basin. Hauling from separator direct to market required 2.17 hours and 2.34 hours in the two areas respectively. Man labor was charged to the wheat crop at the rate of 20 cents an hour.

The horse labor required to grow an acre of wheat amounted to 26.87 hours in the Gallatin Valley and 23.79 hours in the Judith Basin. Hauling from separator to granary required 1.82 horse hours in the Gallatin Valley and 1.36 in the Judith Basin, while hauling direct from separator to market required 3.9 horse hours in the Gallatin Valley and 5.06 in the Judith Basin. Horse labor is charged at the rate of 10 cents an hour.

Equipment charges amount to $0.934 per acre in the Gallatin Valley and $0.624 in the Judith Basin. The equipment cost consists of the following items: Depreciation, repairs, lubrication, and interest.

The total cost of the field operations in growing and marketing wheat was $6.00 per acre in the Gallatin Valley and $5.22 in theJudith Basin. The figures include the charges for man labor, horse labor,

and the use of equipment. The cost per bushel per mile for marketing wheat was $0.013 in the Gallatin Valley and $0.009 in the Judith Basin.

In the Gallatin Valley 60.37 pounds of seed per acre were used at an average cost of $0.015 per pound. In the Judith Basin 48.8 pounds were used at a cost per pound of $0.015.

Chemicals for treating seed cost $0.015 per acre in the Judith Basin and $0.02 per acre in the Gallatin Valley.

The threshing charge was $0.09 per bushel in the Gallatin Valley and $0.102 per bushel in the Judith Basin. This resulted in an acre charge in the two areas of $3.12 and $3.02 respectively.

The total cost of growing an acre of wheat was $18.37 in the Gallatin Valley and $15.83 in the Judith Basin, the average figure being $17.08.

The estimated cost of growing an acre of wheat in Montana in 1918, based on current prices for labor and materials and normal yields, is $20.33.

The Cost of Growing Wheat on Typical Non-Irrigated Areas in Montana

With the breaking up of the range and the development of dry-land agriculture, the wheat crop has become one of first importance in this State. The acreage of wheat in Montana in 1909 was 258,377 acres;* in 1916 it had increased to 1,485,000 acres,** an increase during this seven-year period of over 500 per cent. Because of its peculiar adaptability to conditions that prevail in regions of low rainfall, it seems likely that wheat as a crop of first importance will continue to hold the field against all competitors for years to come. Since it is for the most part sown in the fall in this State, wheat has an enormous advantage over most other crops on the dry land in that it is able to get a two or three weeks' earlier start in the spring and can thus mature its crop before the excessive heat and drought of late summer.

Wheat growing as a business in this State has had its share of ups and downs. Not only have yields been uncertain but prices have fluctuated widely. There have been times when growers have complained bitterly that their crop did not sell for enough to pay the cost of production. Even at the present time, when it seems likely that the greater part of the wheat crop will sell at a figure well up toward the two-dollar mark, growers in some quarters are loud in their protest against this price, insisting that under present conditions it is not sufficient to pay production costs.

As with many other enterprises on the farm, wheat growing is frequently carried on in a very unbusinesslike manner. Few growers indeed have anything like an accurate notion as to what it costs them to grow wheat, neither have they any definite information as to whether they are producing it at a profit or at a loss or what this profit or loss may be. For the purpose of gaining definite information on the business aspects of wheat growing, the farm management department conducted studies on a large number of wheat farms in the Gallatin Valley and the Judith Basin during the seasons of 1915 and 1916.

*Thirteenth Census. **U. S. Dept. of Agriculture Yearbook, 1916.

METHOD OF STUDY

During the summer of 1915 a representative* of this department visited eighty-three farms in the Gallatin Valley and secured data from the operators covering the details of management of the wheat enterprise. Some of the more important items of information secured were as follows: (1) Acreage, yield, and value per bushel of the wheat crop for as many years back as possible; (2) normal acreage of other crops; (3) amount of each class of live stock; (4) cost and duty of machinery used in carrying on the wheat enterprise; (5) man and horse labor requirements for each operation in growing and marketing wheat; (6) direct expense in growing wheat, such as money spent for seed, twine, threshing, etc. Besides these more important items bearing directly upon the cost of production, considerable miscellaneous information was secured relative to the status of the wheat crop and its relation to other farm enterprises. Similar data were collected from 122 farms in the Judith Basin during the summer of 1916.

It may be mentioned at this point that in all cases figures were secured for as many years back as possible in order that the data obtained might represent the normal. In most cases the figures that are used in the following tables are averages for two and in some cases four or more years. It is thought that these data represent normal conditions on the farms in the areas under study and that if they seem not to adapt themselves to present conditions it is because conditions at the moment are not normal.

Figures showing the cost of any operation or the total cost of production are not of any great permanent value. The values of the different items fluctuate so widely that all such figures are apt to soon become inaccurate. The really valuable figures are those which show the amount of each item which goes into the enterprise. When these figures are used and current rates are substituted, it is possible at any time to approximate costs quite accurately.

TYPE OF FARMING ON WHEAT FARMS

Farms in the areas studied are devoted quite exclusively to the growing of wheat. Small acreages of other crops are grown, in most cases, to provide feed for animals. Some farms are devoted so ex-

*Credit is due Mr. R. E. Cannon who assisted in collecting the data that are presented in this bulletin.

TABLE I.—CROPS GROWN IN GALLATIN VALLEY WHEAT AREA
Data from 83 farms, 1914

Crop	Total acres	Acres per farm	Percent of total crop acres	Yield per acre (bushels)
Turkey Red	3,835	46.20	35.85	32.0
Crail Fife	693	8.35	6.48	37.0
Marquis	517	6.23	4.83	31.9
Other wheat	1,505	18.10	14.07	33.7
All wheat	6,550	78.90	61.23	32.9
Barley	1,309	15.80	12.24	
Hay	1,406	16.94	13.15	
Oats	1,431	17.24	13.38	
Total crop acres	10,696	128.86		

clusively to wheat growing that no feed at all is raised, hay and grain being purchased for work animals.

It will be noted from Table II that in the Judith Basin the wheat acreage was more than three times as great as the combined acreage of all other crops. In the Gallatin area the preponderance of wheat is almost as great. The acreage of other crops does not appear to be much more than enough to provide feed for work animals.

TABLE II.—CROPS GROWN IN JUDITH BASIN WHEAT AREA
Data from 122 farms, 1915

Crop	Total acres	Acres per farm	Percent of total crop acres	Yield per acre (bushels)
Turkey Red	21,157	176.3	67.52	32.2
Marquis	2,777	23.1	8.86	25.6
Other wheat	737	6.1	2.35	25.8
All wheat	24,671	205.5	78.73	32.1
Oats	2,823	23.5	9.01	
Barley	717	6.0	2.29	
Other grain	143	1.2	.46	
Hay	2,981	24.8	9.51	
Total crop acres	31,335	261.0		

A very limited amount of stock is kept on these farms. It will be seen from Table III that in the Gallatin Valley there were 5.77 acres of crop per animal unit, including work horses. In the Judith Basin there were 9.14 acres per animal unit. Some farms are entirely devoid of stock except work horses. Most of them, however, have at least one or two cows, a few hogs, and a small flock of chickens.

Farmers quite generally recognize the desirability of keeping more stock, but they are very seriously limited in this direction by the fact that feed and forage crops seem to be poorly adapted to dry lands and do not yield a sufficient quantity of feed to enable them to compete successfully with wheat for the use of land and labor. In other words, land and labor can be used so much more profitably in growing wheat that forage crops are not grown to any great extent and consequently the amount of live stock which it is possible to carry is very much limited.

TABLE III.—AMOUNT OF LIVE STOCK ON FARMS IN THE GALLATIN VALLEY AND THE JUDITH BASIN

Kind of stock	Gallatin Valley		Judith Basin	
	Average number per farm	Animal units	Average number per farm	Animal units
Horses	8.9	8.9	8.36	8.36
Cows	5.2	5.2	6.56	6.56
Young cattle	7.0	3.5	7.5	3.75
Hogs	9.9	1.98	11.2	2.24
Pigs	8.2	.82	7.05	.70
Sheep	5.5	.79	7.6	1.08
Poultry	114.0	1.14	116.0	1.16
Totals		22.33		23.85

Crop acres per animal unit: Gallatin Valley, 5.77; Judith Basin, 9.14.

Note.—An animal unit is the amount of stock of any kind that is equivalent to a mature horse or cow. Each of the following constitutes an animal unit: 1 horse, cow, bull, or steer two years or over; 2 colts or young cattle under two years; 5 hogs; 10 pigs; 7 sheep; 14 lambs; or 100 chickens.

It is a matter of some speculation as to what will be the outcome of dry-land farming in this country. It seems reasonable to suppose that continuous wheat growing will in the course of time so deplete the humus content of the soil that it will be no longer possible to grow even wheat at a profit. In some of the older sections of neighboring States where wheat has been grown continuously for a good many years, yields have become so low that the land is hardly worth farming. If this sort of cropping is continued for a long enough time the productive power of the land must finally reach a point where wheat growing will no longer pay. The only recourse then will be to abandon the land and wait until it can be restored by the slow process of

Nature. It does not seem likely that this thing will ever occur in this State. It seems more reasonable to suppose that, as time goes on and as population increases, economic conditions will bring about a change in the whole system. Due to the increasing demand for food, wheat will probably rise gradually in price. This increase in price will compensate in a measure for the decline in yield. When yields, however, have reached a sufficiently low point and the normal price per bushel has become much higher than it is at present, it seems likely that yields will be benefited to such an extent by alternating with a sod crop that such a system will pay even though the sod crop itself be produced at a loss. When this time comes the greater amount of forage available will permit the keeping of more live stock and the whole system will be on a much more sound and permanent basis. Continuous wheat farming as practiced in this State at the present time is merely a makeshift and must give way to a more permanent type of farming as soon as economic conditions will permit.

CROPPING PRACTICE ON WHEAT FARMS

The system followed in growing wheat in the Gallatin Valley is that in which each crop alternates with a year of summer fallow. The Judith Basin is a much newer wheat region. The average period during which fields have been under cultivation in this area is 8.8 years as compared with 30.9 years in the Gallatin. According to the statement of farmers, wheat yields have not declined even in the Gallatin Valley where the crop has been grown continuously for over three decades. However, from the tables showing labor requirements it will be noted that considerably more work is required in growing a crop of wheat in the older-farmed Gallatin area than is the case in the Judith Basin. Farmers also admit that much more work is required to get the land in shape for a crop of wheat now than was the case formerly. This is pretty good evidence that the humus content of the soil is gradually running down. It indicates pretty clearly that continuous wheat cropping will some day have to give way to a system that is better balanced and more permanent.

Far and away the greatest problem on the dry lands as far as maintaining productiveness is concerned is the matter of keeping up the supply of organic matter in the soil. The summer fallow offers ideal conditions for the loss of this valuable constituent. The

well-aerated condition and the favorable moisture content induced by fallowing cause oxidation to proceed at a rapid rate.

However difficult it may be to do so, it seems that without question some way should be found for returning every pound of wheat straw to the land either directly or after it has been converted into manure by animals. At the present time a large percentage of the farmers in both areas burn all or a part of their straw.

TABLE IV.—DISPOSAL OF STRAW IN THE GALLATIN VALLEY AND JUDITH BASIN WHEAT AREAS

	Gallatin Valley		Judith Basin	
	Number of farms	Percentage of total	Number of farms	Percentage of total
Burn only	14	16.9	61	50.0
Burn and feed	47	56.6	46	37.7
Feed only	22	26.5	15	12.3

One of the best methods of returning straw to the land and one that is practiced successfully by a number of farmers is that wherein the straw is applied to the wheat fields in the fall as a top dressing. This straw has a tendency to protect the field against blowing in the winter and to hold the snow more or less. The following spring the wheat plants grow up through the straw, which continues to benefit the crop by acting as a mulch. By the time the ground is ready for plowing the straw is so far decayed that it can be incorporated with the soil without damage to the next crop.

In the Judith Basin the summer fallow system is not adhered to as closely as it is in the Gallatin Valley. A common practice in this region is to sow wheat after fallow and to follow this with a crop of wheat "stubbled in" or sown directly in the stubble after the preceding crop has been removed. Thus the field is plowed only once in three years and during this period two crops are grown.

Table V shows the relative acreage of stubbled-in wheat and wheat on fallow. It also shows the yields under the two systems.

TABLE V.—RELATION OF CROP PRACTICE TO YIELD OF WHEAT
Data from 122 farms in the Judith Basin, 1915

Crop practice	Total acres	Acres per farm	Yield per acre
Wheat on stubble	4,409	36.1	23.4
Wheat on fallow	12,956	108.0	36.5

It will be noted that the average yield per acre of wheat on summer fallow is 36.5 bushels. The average yield of wheat stubbled in is 23.4 bushels, showing a difference of about 13 bushels per acre in favor of the crop grown on fallow. At present prices this difference in yield would be more than enough to pay the entire cost of growing an acre of wheat, but this difference in yield does not tell the whole story. If wheat were grown only on summer fallow, the amount of land that could be fallowed by the available crew and equipment would set a limit to the acreage of wheat that could be grown. However, it is often the case that after as much wheat as possible is put in on fallow there is still opportunity to put in considerable acreage on stubble. Under these conditions the stubbled-in wheat is not required to compete with the wheat on fallow so far as yields are concerned. By stubbling in a portion of the crop the grower is enabled to furnish men and equipment with a more complete year's work and to add substantially to the farm income. Stubbling-in wheat is a pioneer method which will have to give way to a more intensive practice as the region becomes older and weeds become more troublesome. Farmers all seemed to be of the opinion that in a very few years summer fallowing for wheat would be the universal practice.

Table VI shows the relation of depth of plowing to yields in both regions. The figures seem to run quite consistently in favor of deep plowing. In order to give dependable results observations of this kind would have to run over a series of years. Yields that are given here are averages for two and in many cases for three

TABLE VI.—RELATION OF DEPTH OF PLOWING TO WHEAT YIELDS IN THE GALLATIN VALLEY AND THE JUDITH BASIN

Depth plowed (inches)	Gallatin Valley			Judith Basin			All farms		
	Number of farms	Average depth plowed	Yield per acre	Number of farms	Average depth plowed	Yield per acre	Number of farms	Average depth plowed	Yield per acre
Less than 5	14	4.3	33.4	11	4.2	25.5	25	4.26	29.9
5 to 5.5	38	5.2	34.7	49	5.1	29.2	87	5.12	31.6
6	23	6.0	36.5	47	6.0	30.4	70	6.00	32.4
Over 6	7	7.3	41.8	12	6.9	29.9	19	7.06	34.3

years. The figures at least indicate the desirability of plowing deeply enough to permit the forming of a good seed-bed. On most soils this requires plowing to a depth of six or more inches.

ELEMENTS OF COST IN GROWING WHEAT

Following are the items which must be charged against the cost of growing a crop of wheat: (1) land rental, (2) man labor, (3) horse labor, (4) use of machinery and equipment, (5) seed, (6) chemicals, (7) threshing and coal. To these might also be added interest on each item of cost from the time the cost is incurred until the crop is sold and the money received. Such a charge would be an entirely proper one, but because of the difficulty of arriving at this figure satisfactorily we have thought best not to attempt to include it here.

LAND RENTAL

One of the important items in the cost of growing wheat is the charge for the use of land. In this work we have charged the crop with 6 per cent of the market value of the land annually. It will be recognized that this is a nominal charge as this amount has to take care of interest on the money invested and also taxes on the land. When wheat is grown on summer fallow it is necessary for the crop to bear this land charge for two years.

The average land value in the Judith Basin was $54.63 per acre. Six per cent of this amount computed for two years would give a rental charge of $6.56 per acre. This figure appears to be somewhat lower than the customary cash rental in the region. On six farms that were cash-rented the average rental charge was $3.50 per acre annually. This would make a charge of $7.00 per acre against the crop. The average price per acre of land in the Gallatin Valley was $65.48, the rental charge $7.86. The average cash rental paid by

TABLE VII.—LAND VALUES AND RENTAL CHARGES IN THE GALLATIN VALLEY AND THE JUDITH BASIN

	Gallatin Valley	Judith Basin
Land value per acre	$65.48	$54.63
Rental charge*	7.86	6.56
Cash rental per acre paid by farmers	**7.18	***7.00

*Six per cent of land value computed for two years.

**Data from 11 cash-rented farms. ***Data from 6 cash-rented farms.

eleven farmers in this region was $7.18.

A number of farms in each area were rented for a share of the crop. In nearly all cases the landlord received a third of the crop delivered. With normal yields and prices the cash rent at $7.00 or $7.50 per acre appears to be somewhat cheaper for the tenant than share rent. Under the cash rental system, however, the tenant is obliged to assume all the risk and for this he is entitled to extra compensation.

MAN LABOR

With the methods employed in this State it requires less than a day of human labor to grow an acre of wheat. Table VIII gives the labor requirements for each operation in the two areas. It will be noted that in the Gallatin Valley 8.17 man hours is the total requirement while in the Judith Basin only 6.46 hours are necessary. The high duty of labor as shown by these tables is due to the extensive use of labor-saving machines. Fields are large and from four to six horses are used in every operation.

TABLE VIII.—MAN-LABOR REQUIREMENTS FOR GROWING WHEAT IN THE GALLATIN VALLEY AND JUDITH BASIN

	Gallatin Valley		Judith Basin	
Operation	Number of operations	Man-hours per acre	Number of operations	Man-hours per acre
Plowing	1	2.52	1	2.50
Harrowing	4	1.07	2.04	.47
Disking	2.7	1.47	2.08	1.02
Cleaning seed	1	.18	1	.12
Treating seed	1	.15	1	.10
Seeding	1	.64	1	.53
Cutting	1	.76	1	.57
Shocking	1	1.38	1	1.15
Total man-labor		8.17		6.46

In some cases growers furnish all or a part of the labor for threshing wheat, but more commonly the threshing is done by a furnished crew. In the majority of cases the grain is hauled directly from the thresher to the market or shipping point. In Table IX are shown the labor requirements for marketing wheat in each area.

We have charged the wheat crop for all man labor used at the rate of 20 cents an hour. It is recognized that some of the help that

is hired for short periods receives an amount considerably in excess of this figure. However, when all of the labor that the crop uses is considered, it seems likely that this figure is not far off. It agrees rather closely with the rates for farm labor that have been obtained by cost-accounting studies in this State. The cost of labor of course is subject to change from year to year. When labor is scarce and wages are high, as is the case just at present, this figure would necessarily have to be revised upward in order to more nearly represent the real cost of labor on the farm.

TABLE IX.—AVERAGE DISTANCE TO MARKET AND LABOR REQUIREMENTS FOR MARKETING WHEAT IN THE GALLATIN VALLEY AND JUDITH BASIN

	Gallatin Valley	Judith Basin
Average distance to market or shipping point (miles)	2.25	3.50
Man-hours per acre		
Hauling to granary	1.17	.73
Hauling to market*	2.17	2.34

*Hauling direct from separator.

HORSE LABOR

The records in this department indicate that under normal conditions horse labor usually costs in the neighborhood of 10 cents an hour in this State. Horses as a rule work from 800 to 1,000 hours per year. The cost of their keep varies between $80 and $100 annually. This makes the cost per hour average about 10 cents. Table X gives the horse-labor requirements for growing wheat in each area

TABLE X.—HORSE LABOR REQUIREMENTS FOR GROWING WHEAT IN THE GALLATIN VALLEY AND THE JUDITH BASIN
Data from 205 farms for 1914 and 1915

	Gallatin Valley		Judith Basin	
	Number of operations	Horse-hours per acre	Number of operations	Horse-hours per acre
Plowing	1	11.09	1	12.35
Harrowing	4	4.28	2.04	2.03
Disking	2.7	6.32	2.08	4.63
Seeding	1	2.39	1	2.14
Cutting	1	2.79	1	2.64
Total horse-labor		26.87		23.79

by operations. In the Gallatin area it required 26.87 hours of horse labor to grow an acre of wheat. In the Judith Basin 23.79 hours were necessary.

TABLE XI.—HORSE LABOR REQUIREMENTS FOR MARKETING WHEAT IN THE GALLATIN VALLEY AND THE JUDITH BASIN

	Gallatin Valley	Judith Basin
Average distance to market or shipping point (miles)	2.25	3.50
Horse-hours per acre		
Hauling to granary	1.82	1.36
Hauling to market*	3.90	5.06

*Hauling direct from separator.

USE OF MACHINERY

One of the important costs in the growing of any crop is the charge for the use of machinery. The items that enter into this machinery cost are depreciation, repairs, lubrication, and interest. In some cases shelter is also a charge that should be considered; however, on the majority of farms in the areas studied machines are

TABLE XII.—AGE, LIFE, INITIAL COST, AND PRESENT VALUE OF MACHINES USED IN GROWING WHEAT

Data from 83 wheat farms in the Gallatin Valley

Machine	Number of machines	Cost when new	Age in years	Life in years	Present value
Plows	111	$ 75.30	5.30	10.30	$36.55
Harrows	93	27.47	7.70	15.50	13.82
Disks	92	50.65	4.93	9.73	24.98
Drills	82	105.16	7.67	14.70	50.29
Binders	89	164.62	4.92	9.34	77.90
Wagons	116	111.23	9.82	19.40	54.93

TABLE XIII.—AGE, LIFE, INITIAL COST, AND PRESENT VALUE OF MACHINES USED IN GROWING WHEAT

Data from 122 wheat farms in the Judith Basin

Machine	Number of machines	Cost when new	Age in years	Life in years	Present value
Plows	188	$ 84.65	4.45	10.45	$48.60
Harrows	133	26.95	6.00	12.40	13.91
Disks	143	55.85	4.50	11.05	33.10
Drills	135	126.35	6.14	10.36	51.47
Binders	147	178.66	4.07	7.88	86.38
Wagons	187	121.34	7.30	15.53	64.30

given no shelter and so in this work shelter has been disregarded as an item of cost.

Tables XII and XIII show the age, life, initial cost, and present value of machines in the two areas. It will be noted that wagons have a period of usefulness of from fifteen to twenty years; harrows, disks, drills, and plows last from ten to fifteen years, while binders on the average last less than ten years.

It will be noted from Tables XIV and XV that, in spite of the fact that machines are longer lived in the Gallatin Valley than is the case in the Judith Basin, acre costs are considerably less in the latter area. An explanation for this is found in the fact that farms are larger in the Judith Basin, thus giving an opportunity for using machines to more nearly their full capacity. Some of the items in machinery cost are annual costs. These costs have to be met each year regardless of the extent to which the

TABLE XIV.—COST AND DUTY OF MACHINERY
Data from 83 wheat farms in the Gallatin Valley

Machine	Annual depreciation		Annual repairs	Annual lubri-cation	Annual interest	Total cost	Acres of work	Cost per acre
	Percent	Amount						
Plows	9.7	$7.31	$7.55	$0.63	$2.19	$17.68	81.63	$0.216
Harrows	6.5	1.77	1.21	.00	.83	3.81	96.90	.039
Disks	10.3	5.21	1.69	.74	1.50	9.14	99.90	.091
Drills	6.8	7.15	1.61	.68	3.02	12.46	112.50	.110
Binders	10.7	17.62	11.29	1.63	4.67	35.21	106.40	.330
Wagons	5.7	5.73	3.88	.54	3.29	13.44	90.49	.148

TABLE XV.—COST AND DUTY OF MACHINERY
Data from 122 wheat farms in the Judith Basin

Machine	Annual depreciation		Annual repairs	Annual lubri-cation	Annual interest	Total cost	Acres of work	Cost per acre
	Percent	Amount						
Plows	9.5	$8.10	$7.40	$0.98	$2.92	$19.41	126.3	$0.154
Harrows	8.0	2.18	1.08	.00	.83	4.09	185.1	.022
Disks	9.0	5.05	2.12	1.06	1.98	10.21	171.12	.059
Drills	9.6	12.20	3.00	1.32	3.09	19.61	213.08	.092
Binders	12.7	22.67	9.31	1.94	5.18	39.10	196.26	.199
Wagons	6.4	7.81	3.20	.575	3.86	15.44	156.75	.098

machine is used. These costs make the acre charge for the use of a machine excessive when the machine is used on a limited acreage. One of the best methods of keeping acre costs for machinery down to a minimum is to use the machine as much as possible each year. To do this requires an ample acreage of crop. The crop acreage per farm in the Judith Basin is more than double that in the Gallatin Valley, while the acre cost for the use of machines is less by about a third.

The greatest economy in the use of machinery comes when a farm has a sufficient crop acreage to keep each machine busy for as large a number of days throughout the year as possible. When this point is observed and care is taken to keep machines properly lubricated and adjusted, machinery costs are kept at a minimum. Machines in each area would last longer and depreciation charges would be less if shelter of some kind were more generally provided. It is universally recognized that a cheap, substantial building for housing machinery more than pays for itself in prolonging the lives of machines.

Cost per Acre of Each Field Operation in Growing and Marketing Wheat

It will be noted from Tables XVI and XVII that the cost of marketing an acre of wheat is $0.941 in the Gallatin Valley and $1.072 in the Judith Basin. The average distances to market are 2.25 and 3.5 miles in the two areas respectively. With the

TABLE XVI.—COST PER ACRE OF EACH FIELD OPERATION IN GROWING AND MARKETING WHEAT

Data from 83 wheat farms in the Gallatin Valley

	Man labor		Horse labor				
Operation	Hours per acre	Cost	Hours per acre	Cost	Machinery acre cost	Total cost per acre	Cost per operation
Plowing	2.52	$0.504	11.09	$1.110	$0.216	$1.946	$1.946
Harrowing*	1.07	.214	4.28	.428	.039	.770	.192
Disking**	1.47	.294	6.32	.632	.091	1.116	.413
Drilling	.64	.128	2.39	.239	.110	.439	.439
Cutting	.76	.152	2.79	.279	.330	.515	.515
Shocking	1.38	.276	....	....	....	.276	.276
Marketing	2.17	.434	3.90	.390	.148	.941	.941

*Harrowing 4 times. **Disking 2.7 times.

TABLE XVII.—COST PER ACRE OF EACH FIELD OPERATION IN GROWING AND MARKETING WHEAT

Data from 122 wheat farms in the Judith Basin

Operation	Man labor: Hours per acre	Man labor: Cost	Horse labor: Hours per acre	Horse labor: Cost	Machinery acre cost	Total cost per acre	Cost per operation
Plowing	2.50	$0.500	12.35	$1.230	$0.154	$1.884	$1.884
Harrowing*	.47	.094	2.03	.203	.022	.319	.156
Disking**	1.02	.204	4.63	.463	.059	.726	.349
Drilling	.53	.106	2.14	.214	.092	.412	.412
Cutting	.57	.114	2.64	.264	.199	.577	.577
Shocking	1.15	.230	....	....	....	.230	.230
Marketing	2.34	.468	5.06	.506	.098	1.072	1.072

*Harrowing 2.04 times. **Disking 2.08 times.

average yields of wheat given in Tables I and II this makes a charge of $0.013 per mile per bushel in the Gallatin Valley and $0.009 in the Judith Basin. It may be mentioned that the customary commercial rate in the Judith Basin for hauling grain to market is $0.01 per mile per bushel.

SEED

In the Gallatin Valley 60.37 pounds of seed were used per acre at an average cost of $0.015 per pound. In the Judith Basin 48.8 pounds were used at a cost of $0.015.

CHEMICALS

It is the universal practice in each area to chemically treat seed for the purpose of killing the smut spores. Copper sulphate (vitriol) is commonly used for this purpose in the Gallatin Valley while in the Judith Basin treating with formaldehyde is the usual practice. The indications are that there is little difference in the effectiveness of these two chemicals. The cost per acre for the formaldehyde treatment is somewhat less than for the copper sulphate; however, in either case the cost of treatment is so slight as to be of little significance. The labor cost of treating the seed amounts to more than the cost of the chemicals, but this cost is only from two to three cents per acre. Table XIX gives the cost of treating seed in each area.

THRESHING

Practically all the threshing in these areas is done with a furnished crew. The average rate per bushel in the Gallatin Valley was $0.083, in the Judith Basin $0.095. Charge is also made for the coal that is burned. This amounted to approximately 80 pounds per acre in each area. At the price of coal given in Table XVIII the charge amounted to a little less than 1 cent per bushel. The total threshing charge per bushel was $0.09 in the Gallatin Valley and $0.102 in the Judith Basin.

TABLE XVIII.—COST OF THRESHING WHEAT IN THE GALLATIN VALLEY AND THE JUDITH BASIN

	Gallatin Valley	Judith Basin
Rate charged per bushel for threshing	$ 0.083	$ 0.095
Total cost per bushel for threshing	.0900	.1020
Cost per pound	0.0032	0.0027
Cost of coal per acre	.2579	.2184
Cost of coal per bushel threshed	.0070	.0077
Total cost per bushel for threshing	.0900	.1020

COST OF GROWING AND MARKETING AN ACRE OF WHEAT

It will be noted from Table XIX that the total cost of growing and marketing an acre of wheat was $18.37 in the Gallatin Valley

TABLE XIX.—COST OF GROWING AND MARKETING AN ACRE OF WHEAT IN THE GALLATIN VALLEY AND THE JUDITH BASIN
Data from 205 farms in 1914 and 1915

Item	Gallatin Valley			Judith Basin			Average		
	Amount	Rate	Total	Amount	Rate	Total	Amount	Rate	Total
Man hours	10.34	$0.20	$2.07	8.81	$0.20	$1.76	9.57	$0.20	$1.91
Horse hours	30.77	.10	3.08	28.85	.10	2.88	29.81	.10	2.98
Equipment charge	*	.93	.93	*	.64	.64	*	.785	.78
Land rent	*	7.86	7.86	*	6.56	6.56	*	7.21	7.21
Seed (pounds)	60.37	.0155	.93	48.8	.015	.73	54.58	.0152	.83
Chemicals (pounds)**	.167	.125	.02	.013	.756	.01	....	....	.015
Twine (pounds)	3.2	.114	.36	3.1	.102	.32	3.15	.108	.34
Threshing (bushels)	34.65	.090	3.12	28.4	.103	2.93	31.5	.096	3.02
Total cost.			$18.37			$15.83			$17.08

*Acre charge. **In the Gallatin Valley vitriol is commonly used; in the Judith Basin, formaldehyde.

and $15.83 in the Judith Basin. The average cost for the two areas was $17.08. It is recognized that many of the items of cost shown in this table are much higher at the present time than was the case when these studies were made; however, it is possible by substituting current prices to arrive at a figure which will approximate the present cost quite closely.

ESTIMATED COST OF PRODUCING AN ACRE OF WHEAT IN MONTANA IN 1918, BASED ON AVERAGE YIELDS FOR THE STATE AND CURRENT PRICES FOR MATERIALS

In Table XX appears an estimate of the cost of growing wheat in Montana in 1918. In making this estimate we have used the figures in Table XIX, showing the average amounts of labor and materials used in the two regions under study. We have used current prices for these various materials. This table gives the probable cost of growing an acre of wheat with normal yields and at prices which it seems likely will prevail for labor and materials. These figures indicate that under present conditions the average

TABLE XA.—ESTIMATED COST OF GROWING AN ACRE OF WHEAT IN MONTANA IN 1918

Based on average yields and current prices for labor and materials

Item	Amount	Rate	Total
Man hours	9.57	$0.30	$ 2.87
Horse hours	29.81	.15	4.47
Equipment	*		.90
Land rent	*		6.00
Seed (pounds)	54.58	.032	1.75
Formalin	*		.02
Twine (pounds)	3	.20	.60
Threshing (bushels)	24.8	.15	3.72
Total acre cost			20.33

*Acre charge.

cost of growing an acre of wheat will probably be a little more than $20. In this table man labor has been charged at the rate of 30 cents an hour and horse labor at 15 cents, while the charge for the use of machinery has been raised from 78 cents to 90 cents. Seed is figured at $1.90 per bushel and twine at 20 cents per pound.

Land is probably somewhat higher priced in the regions studied than is the case for average wheat land in the State. Therefore it was thought best to reduce the rental charge from $7.21 per acre

to $6.00 per acre. This amount will take care of the land costs on land worth $50 per acre for the two years that it is devoted to the crop.

In computing the threshing charge we have used the 10-year average yield for the State as shown by the U. S. Department of Agriculture Yearbook for 1916. As this yield is somewhat lower than that in the areas under study we have adjusted our twine requirement to 3 pounds per acre on the basis of the lower yield. It is thought that the figures given in this table will approximate rather closely the amounts that farmers will have to pay for the various items during the present year.

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Plum Pocket and Leaf Gall on Americana Plums

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IMPORTANCE OF AMERICANA PLUMS

Montana is situated practically at the northern limits of plum production. The more tender of the European and Japanese varieties cannot be grown in any part of the State. In the more favored locations west of the continental divide a number of good varieties, such as Bradshaw, Peach, Pond, and Tragedy, that are moderately hardy, can be grown very successfully; but throughout the greater part of the State, including all that vast region east of the continental divide, about the only plums that succeed are the native wild plum (*Prunus Americana* Marshall) and cultivated varieties and hybrids of this species, such as DeSoto, Hawkeye, Wolf, and Wyant. Indeed, much of the north central portion of the United States is largely dependent upon the Americana plums. Hedrick (36) says of it (p. 59), "The domestication of Americana plums is due to the fact that the plums of Europe will not thrive in the Mississippi Valley, the prairie states, nor, for the most part, in the south. The European species are tender both to cold and heat in these regions and they are attacked by those scourges of plum culture, black-knot, leaf-blight, and curculio."

Under these conditions the native plum and its hybrids and horticultural varieties are of peculiar importance. They are easily propagated, thrive under diverse soil conditions, and are not often damaged even by our severest winters. While the fruit is not so large or so good in flavor or texture as many European and Japanese plums yet it is highly prized, and during the last ten years it has actually sold in Montana markets at as high a price as the more standard varieties.

ENEMIES OF THE PLUM IN MONTANA

The growing of Americana plums in this State has been greatly hampered and finally brought to a standstill by a fungous disease and an insect pest, namely, a plum pocket caused by *Taphrina communis* (Sad.) Gies., and a leaf-gall mite, *Eriophyes pruni* Schoene. A leaf curl caused by *Taphrina decipiens* (Atk.) Gies. is of minor importance. With the control of the plum pocket and the leaf-gall mite as described below the planting of these plums may well be encouraged.

PLUM POCKET

The term "plum pocket" is applied to a group of related diseases of plum and cherry in which the fruits become greatly inflated and hollow.

Cause.—There are two forms of plum pocket of especial interest to orchardists. One is caused by *Taphrina communis* (Sad.) Gies., found mostly on *Prunus Americana* and cultivated varieties derived from it but also reported on *P. maritima* Wang., *P. niger* Ait., *P. pumila* L., and *P. subcordata* Bentham. The other is caused by *T. pruni* (Fcl.) Tul. and is troublesome on many different varieties including the European plums, but rarely occurs on *P. Americana*. These fungi are closely related, similar in appearance, and cause similar symptoms. *T. pruni* does not occur in Montana at this time so far as we know. This discussion will, therefore, be confined chiefly to the disease caused by *T. communis*.

When the spores of this fungus attack the fruit the mycelium from them does not at once grow throughout its tissues but is chiefly confined to the epidermis, forcing its way underneath the cuticle. (Fig. 1 a.) A few strands, however, go deeper into the fruit. A few weeks later the fungus breaks out through the cuticle, producing enormous numbers of asci over the entire infected surface, and each of these forms quite regularly eight ascospores. As reported by various authors—Sadebeck (61), Mrs. Patterson (51), and Giesenhagen (28)—these ascospores later divide into numerous conidia. In our material we have found that the ascospores at first possess one nucleus (fig. 1 c), but later, in preparation for the formation of conidia, this nucleus divides into two (fig. 1 d) or even several nuclei. These same authors report the wintering over by a perennial mycelium in the fruit-bearing twigs. We have not made an exhaustive study of this phase of the subject, but we are convinced that most of the twigs bearing diseased fruits do not have such a mycelium and most of the plums are infected by spores and not by direct extension of mycelium from the twigs bearing them. Our success in controlling the disease by spraying would support these microscopical findings. The fungus has been best described by Sadebeck (61), Atkinson (1), Mrs. Patterson (51), and Giesenhagen (28), but they have not made clear its full life history. So far as known only one crop of spores is formed, and these are distributed in midsummer;

FIG. 1. Sections through infected plums: a, Invasion of fungus under the cuticle of the epidermal cells. b, Fungus breaking through cuticle. c, Ascus with mature binucleate spores. d, Young ascus with uninucleate spores. e, Ascospores dividing to form conidia. All magnified 1110 times.

but at this time the young, healthy fruits seem no longer susceptible to attack. No new fruit infections are known to occur from this time until the next blooming period of the host.

Symptoms.—A week or two after the blosoms wither, when the fruits are one-fourth to one-half inch in diameter, small whitish spots appear on them, usually one to three on each. These are greenish-white in color, much elevated, and very spongy in texture (fig. 2). They enlarge rapidly until usually the entire plum is involved. At

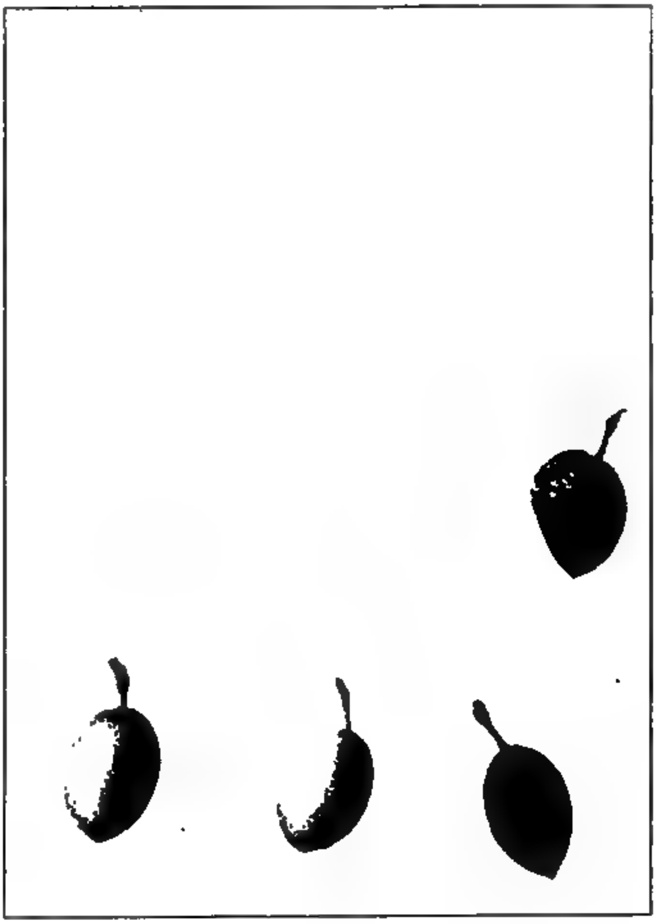

FIG. 2. Healthy and diseased plums, not fully developed, for comparison. Natural size.

this time the stone and seed are only slightly developed and become broken away from the vascular bundles that supply them with water and food and consequently shrivel and disappear. The infected fruits enlarge rapidly and become spongy and then hollow (fig. 3), hence the names "plum pockets," "pocket plums," "bladder plums," and "fools." When full-grown they are three or four times the size of normal plums and leathery in texture. (Fig. 4.) They drop before normal fruit begins to ripen.

Damage done.—Plum pocket is extremely common on Americana plums in central and eastern Montana, and in many other places in

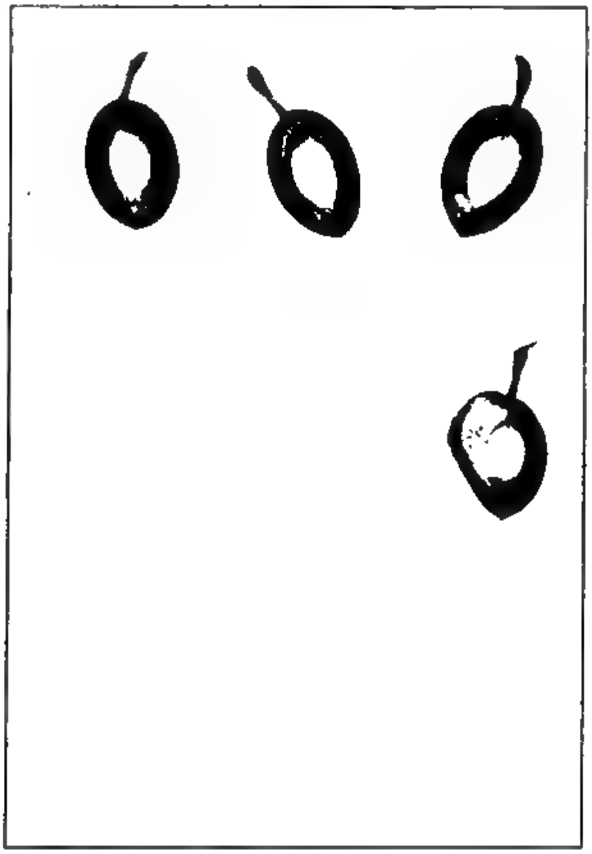

FIG. 3. Internal view of young healthy and diseased plums, showing spongy structure. Natural size.

the Missouri and Mississippi valleys. It usually starts on a few trees in the orchard and gradually spreads to others. When a tree becomes infected it continues to bear diseased plums year after year if left untreated. When the disease has become well established in an orchard it is not unusual to find affected fruits on nearly every tree, and on the worst ones 50 to 90 per cent of the fruits are diseased every year. When a heavy crop is set and the disease is not too severe, it will occasionally result in a proper thinning of the fruit, but this combination is uncommon. We know of entire orchards of good bearing treees having been removed because so few healthy fruits were obtained from them. These orchards were not large, but they were the pioneer test orchards that should have determined whether or not it will be profitable to grow this fruit. Indeed we know of very few plum orchards or even wild thickets in this State east of the continental divide that are free from plum pocket.

FIG. 4. Well developed pocket plum and young healthy ones for comparison in size. Two thirds natural size.

LEAF GALL

In our experiments for the control of plum pocket we found leaf gall so abundant on some of the trees that it was likely to seriously complicate the results.

Cause.—These leaf galls are caused by a mite (*Eriophyes pruni* Schoene) which hibernates under the bud scales. When the buds open these mites crawl forth, seeking the tender young leaves, which they puncture, forming pimples that soon develop into galls.

Appearance.—The galls when fully developed are one-fourth to one-half inch long and one-eighth inch or less in diameter and strongly tinged with red. They are hollow, and the mites live inside. Most of the galls protrude from the upper side of the leaf, either scattered or in dense tufts. (Fig. 5.)

Damage done.—These galls do not kill the leaves outright, but if numerous they seriously interfere with normal functions. Often they are so numerous as to distort a large portion of the leaf surface of the tree.

FIG. 5. Twig showing leaf galls and pocket pl[illegible] Half natural [illegible]

LEAF CURL

Many of the plum trees in the Yellowstone Valley are more or less affected with a leaf curl caused by *Taphrina decipiens* (Atk.) Gies. (Fig. 6.) This disease has become so abundant in certain trees that considerable damage is done, but for the most part it is scattered, though steadily increasing in prevalence.

FIG. 6. Twig affected with leaf curl. Two-thirds natural size.

CONTROL EXPERIMENTS

In the spring of 1913 the authors, in response to repeated complaints that plum pockets and leaf-gall mites were making plum growing unprofitable, began work intended primarily to find a preventive for plum pocket but incidentally including leaf gall and leaf curl.

Plum pocket.—Some attempts have been made to control by spraying the plum pockets caused by *Taphrina pruni*, but until recently none have been succeessful. This may be due in part to the fact that until within the last few years Bordeaux mixture was the fungicide generally used for spraying and the plum foliage is very sensitive to burning by this mixture. Kirk (13) recommends spraying for the control of *Taphrina pruni* but does not give experimental data in support of this recommendation. In a very recent paper Stakman and Tolaas (73) have shown that while the plum pocket can not be perfectly controlled by a single season's spraying, yet the cumulative effect of spraying every year will practically eliminate it even from badly infested trees.

We find no records of spraying experiments for *Taphrina communis.*

Our experiments were conducted in three orchards near Billings, Montana, during the years 1913 to 1917, inclusive. These orchards contained a mixture of native wild plum and several cultivated varieties of it. So far as our observations have gone Wolf and Wyant have proven rather susceptible to plum pocket, while DeSoto and Hawkeye were much more resistant.

As plum foliage is easily injured by spray mixtures we made no attempt to use Bordeaux mixture but started out with self-boiled lime sulphur—8 pounds lime and 8 pounds sulphur to 50 gallons of water. The lime was slaked with hot water, and as soon as it was boiling actively the sulphur (flowers) was added. The mixture was stirred until boiling had nearly ceased, after which it was allowed to stand for ten minutes; then enough cold water was added to make a total of 50 gallons. Later, dilute factory-boiled lime-sulphur was used. This was the Hellgate brand manufactured in Missoula, Montana, and testing 28° Baume. It was diluted 1 part to 50 parts of water.

The fungicide was applied during the years 1913-1915 with a Meyers barrel pump and in 1916 and 1917 with a Morrell and Morley

"Eclipse No. 4," maintaining a pressure of about 50 pounds. The hose was fitted with a Bordeaux nozzle.

In 1913 a late spring frost destroyed the crop almost completely.

In 1914 frost destroyed the greater part of the crop, but enough remained to give some results indicating that the disease could be controlled, to some extent at least, by spraying.

In 1915 conditions were more favorable and the results obtained are shown in Table I. In all our work the "dormant" spray was given just before the first winter fruit buds began to break. The "pink" spray was given when nearly all the fruit buds had broken, but only a few flowers had opened. It should be said that different varieties and strains of the plum did not open quite together. The "petal" spray was given when one-half to three-fourths of the petals had withered.

All the trees selected for spraying work and checks were known to have producted many pocket plums.

TABLE I.—SHOWING CONTROL OF PLUM POCKET WITH SELF-BOILED LIME SULPHUR

Tree No.	When sprayed (1915)				Results	
	I Pink	II Petal	III	IV	Total No. fruits	Per cent diseased
1	April 23	....	....	....	450	0.4
2	April 23	....	....	....	400	0.3
3	April 23	....	....	....	500	1.6
4	April 23	May 7	....	....	100	0
5	April 23	May 7	....	....	250	0
6	April 23	May 7	....	....	100	0
7	April 23	May 7	May 19	....	1300	0.1
8	April 23	May 7	May 19	....	500	0
9	April 23	May 7	May 19	....	75	0
10	April 23	May 7	May 19	June 3	1350	0
11	April 23	May 7	May 19	June 3	175	0
12	April 23	May 7	May 19	June 3	200	0
13	....	May 7	....	....	1200	1.2
14	....	May 7	May 19	....	1100	1.9
15	....	May 7	May 19	June 3	1050	0.
16	Unsprayed				900	55.5

Note: On most of these trees the number of healthy plums was carefully estimated rather than actually counted.

Table I shows that spraying can be made quite effective against this disease. On more than half of the sprayed trees not a single

pocket plum could be found, while the highest percentage of diseased fruit was 1.6. The check, on the other hand, showed 55.5 per cent diseased. At the time the fourth application was given the disease was already showing extensively on the unsprayed trees.

To determine whether the effects of spraying extend beyond one year a set of trees sprayed with self-boiled lime-sulphur in 1915 was left unsprayed in 1916 but notes were taken both years on the prevalence of the disease.

TABLE II.—SHOWING THAT SPRAYING OFFERS LITTLE PROTECTION AGAINST PLUM POCKET THE SECOND SEASON AFTER APPLICATION

	When sprayed (1915)				Results in 1915		Results in 1916	
Tree No.	I Pink	II Petal	III	IV	Total No. fruits	Per cent diseased	Total No. fruits	Per cent diseased
1	April 23	....	....	....	400	2.	46	41.3
2	April 23	....	....	....	1000	0.2	54	31.5
3	April 23	May 7	....	....	800	0.1	10	40.
4	April 23	May 7	....	....	1050	0.1	0	0
5	April 23	May 7	May 19	....	700	*2.8	2	0
6	April 23	May 7	May 19	June 3	275	0.	20	0
7	Unsprayed				800	75.	....	....
8	”				1000	90.	....	....
9	”				700	55.	....	....
10	”				3000	90.	....	....
11	”				....	....	428	7.5
12	”				....	....	117	20.5

Note 1. On most of these trees the number of healthy plums was carefully estimated rather than actually counted.

*Note 2. All the diseased fruits, 20 in number, on this tree were on one branch, indicating that this branch was missed when the most important application was given.

The season of 1916 was not so favorable to the disease as that of 1915 and it was much less prevalent on unsprayed trees. Also the crop was lighter. Table II indicates, however, that the effects of spraying last only for a season. The comparison is somewhat complicated by the fact that we were obliged to use different check trees in 1916.

In 1916 it was decided to try both self-boiled lime-sulphur and

the factory-boiled product (28° Baume diluted 1 to 50), hoping that the latter would prove equally effective, as its preparation is much simpler for the orchardist. It had also been observed that so many infections were visible within two weeks from the time the petals wither that the later sprays were worthless. Consequently only two applications were given. The results are shown in Tables III and IV.

TABLE III.—SHOWING CONTROL OF PLUM POCKET WITH SELF-BOILED LIME-SULPHUR

	When sprayed (1916)		Results	
Tree No.	I Pink	II Petal	Total No. fruits	Per cent diseased
1	April 20	....	32	0
2	April 20	....	17	0
3	April 20	May 9	261	0
4	April 20	May 9	438	0
5	April 20	May 9	0	0
6	April 20	May 9	165	0
7	April 20	May 9	52	0
8	....	May 9	3	0
9	....	May 9	174	0
10	....	May 9	121	0
11	....	May 9	115	0
12	....	May 9	146	0
13	....	May 9	306	0
14	Unsprayed		2	0
15	”		130	1.5
16	”		25	36.0
17	”		12	41.6

The control by spraying with self-boiled lime-sulphur was absolutely perfect. Not a single diseased plum could be found on a sprayed tree.

The factory-boiled lime-sulphur likewise gave perfect control while the six unsprayed checks (in Tables III and IV combined) with a total of 714 plums had 72 of them diseased, or an average of 10 per cent. As already noted 1916 was a poor year for both plum pocket and plums.

If 1916 was an unfavorable year for plum pocket, 1917 was quite the reverse, both for the disease and for spraying. The weather

TABLE IV.—SHOWING CONTROL OF PLUM POCKET WITH DILUTE COMMERCIAL LIME-SULPHUR

Tree No.	When sprayed (1916) I Pink	When sprayed (1916) II Petal	Results Total No. fruits	Results Per cent diseased
1	April 20	....	2	0
2	April 20	....	0	0
3	April 20	....	7	0
4	April 20	....	2	0
5	April 20	May 9	0	0
6	April 20	May 9	386	0
7	April 20	May 9	0	0
8	April 20	May 9	52	0
9	....	May 9	980	0
10	....	May 9	48	0
11	Unsprayed		428	7.5
12	”		117	20.5

records taken at the Billings Weather Bureau station during the month of May show the following daily precipitation:

May 1 0.06 in.	May 8 0.00 in.	May 16 0.00 in.	May 24 0.43 in.
” 2 .02 ”	” 9 .00 ”	” 17 .00 ”	” 25 .06 ”
” 3 .00 ”	” 10 .00 ”	” 18 .00 ”	” 26 .04 ”
” 4 .49 ”	” 11 .00 ”	” 19 .02 ”	” 27 tr.
” 5 .51 ”	” 12 .00 ”	” 20 .32 ”	” 28 .13 ”
” 6 .00 ”	” 13 .00 ”	” 21 .22 ”	” 29 .76 ”
” 7 .00 ”	” 14 .00 ”	” 22 .02 ”	” 30 .93 ”
	” 15 .00 ”	” 23 .00 ”	” 31 tr.

From the records it may be seen that the “dormant” and “pink” sprays were given during a period of fair weather, but that the “petal” spray was both preceded and followed by frequent rains.

It had been decided from previous work that the disease could be controlled by a single application of lime-sulphur, and the work of 1917 was principally to confirm this belief and to determine which is the best time for spraying. Consequently each tree was sprayed but once—different groups on different dates.

Table V shows what can be done to control pocket plum under much less favorable conditions than those during the preceding years of the experiment. The results were by no means perfect, and yet much benefit was derived from the first and the second sprays. The third application, made when most of the petals were withering,

gave little or no benefit either because it was too late or because it was washed off by rain.

TABLE V.—SHOWING CONTROL OF PLUM POCKET WITH DILUTE COMMERCIAL LIME-SULPHUR UNDER UNFAVORABLE CONDITIONS, I. E., A RAINY PERIOD

Tree No.	When sprayed (1917)			Results	
	I Dormant	II Pink	III Petal	Total No. fruits	Per cent diseased
1	May 8	....	....	304	1.3
2	May 8	....	....	*....	
3	May 8	....	....	110	6.4
4	May 8	....	....	91	7.7
5	....	May 16	....	100	25.
6	....	May 16	....	200	13.
7	....	May 16	....	1400	.8
8	....	May 16	....	70	2.9
9	....	....	May 27	700	80.0
10	....	....	May 27	400	85.0
11	....	....	May 27	450	85.0
12	....	....	May 27	*....	
13	Unsprayed			1800	46.0

*Label lost.

From our experiments extending through the last five years we feel very certain that the plum pocket caused by *Taphrina communis* can be controlled without serious difficulty, excepting, perhaps, in regions or seasons having very frequent rains through the blooming period. To what extent the same treatment will control the form caused by *T. pruni* is problematic. The two fungi are very closely related and appear to have very similar life histories. It is probable that in both forms some fruits are infected by the extension of a perennial mycelium in the twigs and others by spores alighting on the surface. There seems little reason to suppose that the infection from a mycelium in the twigs can be controlled by spraying, nor, on the other hand, that the infection by spores can not be so controlled. It seems fair to expect, then, that *T. pruni* can be controlled by spraying to whatever extent the spores are responsible for fruit infections, and the work of Stakman and Tolaas, reviewed on page 175, supports this expectation.' We have had no opportunity in this State to test the applicability of this hypothesis.

Leaf-gall mite.—Leaf galls were so prevalent on many of the

trees used in experiments for the control of plum pocket that it was thought best to devise some means of reducing them. Accordingly in 1914 all the trees used in that season's work were given a late "dormant" spray of lime-sulphur, 28° Baume, diluted 1 to 6. Only a small number of galls appeared on any of these trees. In 1915 it was noted that none of the trees that were sprayed as indicated in Table I had many galls, while the check tree and many others in the orchard were badly infested. The results in 1916 were similar.

These tests indicated that if trees are sprayed in the dormant condition or in the pink, even with dilute lime-sulphur, the number of galls is greatly reduced, but as no records had been made the previous season on the prevalence of the galls on these trees and as some of them undoubtedly were freer from it than others, a more definite experiment on a small scale was planned. In the summer of 1916 a number of plum trees on which the galls were very abundant were selected and labeled. In 1917 these were sprayed with Hellgate lime-sulphur, 28° Baume, diluted 1 to 50. The results are shown in Table VI.

TABLE VI.—SHOWING CONTROL OF LEAF MITE WITH DILUTE FACTORY-BOILED LIME-SULPHUR

Tree No.	When sprayed (1917) I Dormant	II Pink	Results: Prevalence of mite galls
1	May 8	....	Very few
2	May 8	....	Very few
3	May 8	....	None
4	....	May 16	Abundant
5	....	May 16	Very abundant
6	....	May 16	Very abundant
7	....	May 16	Very abundant
8	Unsprayed		Very abundant
9	Unsprayed		Very abundant

From this table we can see that the "dormant" spray, even quite dilute, reduced the mite to such an extent that little damage was done, but that the "pink" spray had little effect upon it. In 1915 and 1916 the "pink" spray gave good control but the "petal" spray much poorer.

Plum leaf curl.—In the summer of 1916 a number of trees showing leaf curl and twig distortions caused by *Taphrina decipiens*

were selected and labeled. In the spring they were sprayed with Hellgate lime-sulphur, 28° Baume, diluted 1 to 50, and each tree was given a single application, three of them in the dormant condition, two of them in the pink condition, and three of them when the petals were withering. No apparent benefit was derived in the control of the leaf curl. This was not surprising, however, as the mycelium quite regularly hibernates in the twigs and the spread by spores to healthy twigs is very slow.

CONCLUSIONS

1. The native plum and varieties derived from it are about the only ones that can be grown successfully in central and eastern Montana.
2. These plums are highly prized and sell for good prices in Montana markets.
3. The growing of these plums has been made unprofitable by plum pocket and leaf-gall mite.
4. The plum pocket can be very well controlled by spraying with lime-sulphur,—either self-boiled 8-8-50, or factory-boiled 28° Baume, diluted 1 to 50, or 32° Baume, diluted 1 to 60.
5. Only a single application is necessary, and this may be given at any time from a late dormant condition to the time the flowers begin to open.
6. The effects of spraying appear not to extend over more than one season.
7. Both microscopical examination and the results of spraying indicate that while a perennial mycelium occurs in some twigs most of the fruits are infected by spores.
8. To what extent the measures here used to control *Taphrina communis* will affect *T. pruni* remains to be proved, but it seems well worth while to try "dormant," "pink," and "petal" sprays on it.
9. The leaf-gall mite of plum is easily controlled by spraying with dilute lime-sulphur while the trees are still dormant, and in some seasons when the buds are in the pink, but after the petals fall it is too late to get the best results.
10. Spraying is not likely to control the leaf-curl of plum.

RECOMMENDATIONS

1. Now that a simple practical way has been discovered for the control of this plum pocket and the leaf-gall mite, the growing of

Americana plums should be encouraged in eastern Montana, especially in the valleys of the Yellowstone River and its tributaries. Small home orchards of this fruit should become rather common but the extent to which it may be raised commercially remains to be determined.

2. Limited observations indicate that the better strains of the wild plum, and DeSoto, Hawkeye, Wolf, and Wyant, derived from it, are well suited to the Yellowstone Valley.

3. To control plum pocket or leaf-gall mite or both, give one application of lime-sulphur (28° Baume, diluted 1 to 50) just before the fruit buds open. If rain follows within two days after spraying, repeat the operation.

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Fifteenth Annual Report of the State Entomologist of Montana

The destructive grasshopper (*Melanoplus*) of 1917

BY

R. A. COOLEY

Fifteenth Annual Report of the State Entomologist of Montana

INSECT PESTS OF 1917

THE MITES AND TICKS (ACARINA)

Red Spider (*Tetranychus bimaculatus* Harvey). Red spiders did considerable damage to raspberries in various parts of the State. The older growth was most seriously damaged and in many cases was completely killed. The new growth was severely injured later in the season. Control experiments were carried out with various insecticides with considerable success.

Pear-Leaf Blister Mite (*Eriophyes pyri* Pagnat). Pear-leaf blister-mite was reported as being injurious to apples in the Bitter Root Valley and other localities in the western part of the State. Some control experiments against this insect were carried on in conjunction with the State Board of Horticulture. As had been previously discovered, lime sulphur, sprayed when the buds were swelling, gave satisfactory results.

COCKROACHES AND GRASSHOPPERS (ORTHOPTERA)

Cockroaches (*Blatta germanica* Linn.). As usual, there were a few inquiries concerning the eradication of cockroaches in houses and business establishments.

Grasshoppers (*Melanoplus* sp.). A grasshopper outbreak, covering the lower Bitter Root Valley, Missoula County, the Flathead Indian Reservation, and Tobacco Plains was the most outstanding feature of the year. Smaller outbreaks occurred in the Missouri Valley between Three Forks and Townsend. Poisoned bran mash was used earlier in the season, followed by grasshopper-catching machines. The farmers caught many bushels of 'hoppers to use for chicken feed.

Shield-Backed Locust (*Peranabrus scabricollis* Scud.). This insect was found doing damage near Ronan, along with the *Melanoplus* spp. in the general outbreak. It did not take the poisoned bran mash as readily as did the *Melanoplus*.

THRIPS (THYSANOPTERA)

Grain Thrips (*Anaphothrips striatus* Osb.). The sterility of

oats, causing a considerable loss in the crop, was noticed again this year. It is due to this insect, which attacks the ovary before the head leaves the boot and so injures it that the flower produces no kernel.

THE TRUE BUGS, PLANT LICE, ETC. (HEMIPTERA)

Potato Bug Feeder (*Perilus claudus* Say). This strikingly colored Pentatomid was found in many instances feeding on the larvae of the Colorado potato beetle, *Leptinotarsa decemlineata*

Bedbugs (*Cimex lectularia* Linn.). Inquiries concerning the control and eradication of bedbugs were frequent. Our former fumigation experiments were repeated, and good results were obtained.

False Chinch Bug (*Nysius ericae* Uhl.). This insect was reported many times, being mistaken for the true chinch bug. It becomes exceedingly plentiful at times and is often accused of doing damage to wheat, though we have no records showing this to be true. It is often the cause of considerable damage to the younger and tenderer portions of vegetables in gardens.

Campylenchia curvata Fabr. This insect was sent in as doing damage to alfalfa. Alfalfa stems were sent in with the epidermis scraped off and punctures in the stems made in feeding and ovipositing. Many of the stems had eggs in them, several to one puncture.

Sugar-Beet Root-Louse (*Pemphigus betae* Doane). Wherever sugar beets have been grown, this insect has obtained a foothold. In the Yellowstone Valley the losses are considerable, due to lessened tonnage and a lowered sugar content of the beets.

Cabbage Aphis (*Aphis brassicae* Linn.). Cabbage aphis did not seem so plentiful this year as in previous years in spite of the increase in the number of gardens and the lack of care in a great many of them.

Apple Aphis (*Aphis pomi* DeG.). This insect was held somewhat in check by the late, cold spring and dry summer so that it was not as plentiful as heretofore. It has always been an important pest of apples but caused little damage this season.

Cottonwood Aphis (*Arctaphis* sp.). This insect seems to be spreading rapidly in this State and causing considerable damage to cottonwoods. Where these trees are the principal shade tree the damage becomes rather important. Badly infested trees lose their

leaves early in the summer, and in many cases the exuded honey dew is a considerable nuisance.

Fall-Grain Aphis (*Macrosiphum* sp.). There were inquiries regarding a species of aphis which was found on heads of nearly ripened wheat. It turned out to be a species of *Macrosiphum*, which is commonly found on wheat in the late summer but which apparently does no damage.

The Western Wheat Aphis (*Brachycolus tritici* Gill.). This insect was practically unknown this year. Heretofore it has caused serious losses in wheat, but in 1916 it was scarce, owing perhaps to the heavy winter-killing of wheat, and this year the winter-killing was greater and the insect so scarce that enough could not be found to continue the research studies.

Woolly Apple Aphis (*Schizoneura lanigera* Hausm.). The woolly aphis caused considerable damage in the Bitter Root Valley this season. It was exceedingly plentiful, more so than last season.

The Elm Gall Louse (*Schizoneura americana* Riley). Elm trees in various localities of the State suffered from the attacks of this insect. Some of the trees were very seriously affected, maturing little or no new growth.

Oyster Shell Scale (*Lepidosaphes ulmi* Linn.). This insect is becoming very abundant and troublesome in the small uncared-for orchards in western Montana. The thorough and consistent use of lime-sulphur sprays will hold it in check.

MOTHS AND BUTTERFLIES (LEPIDOPTERA)

Imported Cabbage Butterfly (*Pontia rapae* Linn.). The cabbage worm caused a great deal of loss in all localities of the State. The small gardens in the cities suffered the worst from this pest, as they were not as well taken care of as the large gardens. Zinc arsenite was substituted for Paris green in control work.

Cutworms (*Noctuidae*). Besides some species of cutworms attacking wheat, garden cutworms were abundant everywhere in the State. Reports of injury to all kinds of garden plants and requests for control information were frequent. Peas, beets, and cabbage seemed to suffer the most injury though other plants were frequently attacked.

Euxoa tristicula Morr. This cutworm caused considerable losses in wheat in the northern part of the State. As it works almost

entirely below the surface of the ground the control offers a considerable problem. Poisoned bran mash seems entirely ineffective.

Bud Moth (*Tmetocera ocellana* Schiff.). The fall brood of the bud moth did considerable damage to the apples this year.

Mediterranean Meal Moth (*Ephestis kuehniella* Zell.). Stored food products in the line of cereals were frequently found to be infested with the larvae of this moth. It was also reported in ground feed, stored in bins. Opening up the mills in zero weather proved an effective means of control.

Indian Meal Moth (*Plodia interpunctella* Hubn.). This tiny reddish moth was reared from dried fruit shipped from California and condemned by the State Board of Health. The shipment consisted of pears, peaches, prunes, figs, and raisins, all infested to a greater or less degree.

Clothes Moths (*Tineola biselliella*). This common household pest was not reported this season as much as heretofore. Fumigation with cyanide of potassium was highly successful against it in a few instances where it was reported.

FLIES (DIPTERA)

Leather Jackets (*Tipulidae*). Larvae of a tipulid, probably *Tipula angustipennis*, were found in great numbers in a damp place in a wheat field. The farmer who saw them, first thought they were wireworms. No damage was done by them.

Mosquitoes (*Culicidae*). Some parts of the State were troubled with mosquitoes but owing to the very dry year they were not as bad as usual. No attempts were made at organized control work because of lack of funds.

Clover Seed Midge (*Dasyoneura leguminicola* Lint.). This insect was caught in rather large numbers in clover at Arlee. It has apparently been present there for the last couple of years and has caused some loss in the clover seed crop, though never reported before. It was not found in any other locality, though it may be more or less generally present.

The March Fly (*Bibio albipennis* Say). Many farmers noticed this fly crawling on their wheat plants last spring, and suspected it of doing some damage. Inquiries regarding it were frequent, and any queer injury or unusual appearance of the plants was attributed to this insect, even though it is apparently harmless.

Horse Flies (*Tabanidae*). In the mountainous localities, horseflies were abundant most of the summer, causing considerable inconvenience to campers and people whose business required their presence in the mountains.

Currant Fruit Fly (*Epochra canadensis* Leow.). Very few currants were gathered in parts of Montana this year due to the injuries caused by this insect. Some poison bait sprays have been used with some success.

Wheat Sheath Miner (*Cerodontha femoralis* Meig.). The losses caused by this insect were not as great as previously. Control measures carried on in one locality seemed to have greatly decreased them.

Stem Maggot of Wheat (*Meromyza nigriventris* Macq.). This insect, in localities where the control of *Cerodontha femoralis* was carried out, was effectively controlled at the same time. The damage done in other places was difficult to estimate due to the losses through drought.

The Nose Fly (*Gastrophilus haemorrhoidalis* Linn.). The nose fly has gradually spread over the entire State and causes more and more trouble in the using of horses. A solid piece of leather from bit ring to bit ring just wide enough to protect the lips is the best protection.

Onion Maggot (*Phorbia ceparum* Meade). The onion maggot was a serious pest of both onions and radishes this year, wherever they were grown.

The Cabbage Maggot (*Phorbia brassicae* Boche). Cabbages grown in the northwestern portion of the State were severely injured by this maggot. Other parts of the State were almost free from any loss of this kind.

THE FLEAS (SIPHONAPTERA)

Fleas (*Siphonaptera*). Inquiries for flea control measures were received this year. The human flea, *Pulex irritans*, was the most common offender. This also lives on mice, which were in some cases the original source of infection.

THE BEETLES (COLEOPTERA)

The Larder Beetle (*Dermestis lardarius* Linn.). The usual inquiries regarding this pest of food products were received in this

office. This insect is perhaps more plentiful and does more damage than is ordinarily realized, and in these days of saving all food products, it should be more thoroughly looked into by the housekeeper.

Wireworms (*Elateridae*). The true wireworms have been held responsible for considerable damage to wheat in various places. They have caused some losses in potatoes by boring into the tubers, rendering them unfit for use.

Dung Beetle (*Aphodius inquinatus* Hbst.). The swarms of these insects in the spring and fall attracted considerable attention among farmers, especially those working in the fields where the beetles were flying and feeding on fresh manure. Some farmers were rather concerned regarding this insect, fearing it might be a pest of some kind.

June Beetle (*Lachnosterna* sp.). Beetles of this genus were unusually plentiful in eastern Montana the past season. They were reported as being so abundant that campers were greatly annoyed by their hitting the tent and alighting on the bed. Beetles were even found literally piled against the sides of dwellings where they had struck and fallen to the ground. No damage was reported as having been done by the larvae.

A Sunflower Pest (*Chrysomea exclamationis* Fab.). This beetle, resembling a Colorado potato beetle, was found in great numbers on wild sunflowers and some times on cultivated ones. Where sunflowers are grown for use in the silo, this insect is liable to become a serious pest.

Flea Beetles (*Epitrix* sp.). Flea beetles were reported on all garden crops. Potatoes and beets were injured the most, but turnips, radishes, and other vegetables were not free from attack.

Cottonwood Blotch Miner (*Odontota* sp.). Reports of injury caused by this insect came from the western part of the State, though in past years it has been generally distributed over all parts of Montana.

Cottonwood Leaf Beetle (*Lina scripta* Fab.). Reports of injury by this insect were not as plentiful as usual, and injury was not noticed by State workers.

Colorado Potato Beetle (*Leptinotarsa decemlineata* Say). The Colorado potato beetle was more plentiful this year than last and, owing to the fact that Paris green was so very expensive, many

people were at a loss how to get rid of them. In many places potato plots were practically ruined before the owner realized it. Arsenite of zinc was recommended as a substitute for Paris green, to be used pound for pound, and results were very successful.

False Wireworms (*Eleodes* sp.). False wireworms were reported to be injuring wheat in widely separated localities about the State. Some fields were found where the injury was doubtless due to false wireworms, but some were also found where other agencies caused most of the damage attributed to this pest.

The Saw-Toothed Grain Beetle (*Silvanus surinamensis* Linn.). This insect was found in a carload of dried fruit which was condemned by the State Board of Health. The fruit, consisting of prunes, peaches, figs, raisins, and pears, was unfit for use and a complete loss. The fruit was shipped from California.

Blister Beetles (*Epicauta maculata* Say and *E. Pennsylvanica* D. G.). These beetles are both friends and enemies, feeding on various crops in the adult stage and on grasshopper eggs in the larval stage. They were unusually plentiful in the localities heavily infested with grasshoppers this season.

Nuttall's Blister Beetle (*Cantharis nuttalli* Say). In a few instances alfalfa was reported to have been injured by Nuttall's blister beetle. The damage was not extensive, nor were the reports of widespread origin.

Lesser Clover Leaf Weevil (*Phytonomus nigrirostris* Fab.). This enemy of clover caused considerable damage in western Montana. It feeds on the heads and young leaves of clover, causing a loss in the seed crop as well as a lowering of the hay yield.

Currant Weevil (*Pseudanthonomus validus* Dietz). This weevil, in cooperation with the fruit fly, was responsible for some of the currant losses. It is not so readily noticed, however, as it attacks the currants before they are beginning to turn, causing them to fall to the ground and dry up.

BEES AND ALLIED FORMS (HYMENOPTERA)

Wasps (*Vespidae*). A report was sent in to this office of wasps causing considerable loss by feeding on ripened or partially ripened strawberries, making them unfit for use. While wasps show a decided liking for fruit, it is not often that they are the cause of any loss.

Leaf Cutter Bees (*Megachile* sp.). Certain species of trees and shrubs, especially ash trees and rose bushes, suffered considerably from the depredations of these insects. In one instance a few rose bushes were almost entirely defoliated, only the midrib of the leaves being left.

Willow Saw-Fly (*Pteronidia ventralis*). Willows used as shade trees were reported as being seriously injured by the larvae of the willow saw-fly.

Pear or Cherry Slug (*Eriocampoides cerasi* Linn.). Cherry trees in the western part of the State suffered from the attacks of this pest. The somewhat flattened green slugs feed on the leaves and completely skeletonize them, giving the trees a brownish appearance.

Ants (*Formicina*). Ants continue to be reported as one great source of trouble to the housekeeper. Usually a little concerted action and careful use of carbon bisulphide will control them.

ECONOMIC ENTOMOLOGY AND THE WAR

The fact of the world's shortage of food supplies is now well known by the American people. It is not as well known that insects annually destroy about ten per cent of the agricultural output of the nation—an amount sufficient to relieve to a considerable extent the pressure at this critical time. The first year of the war brought us in Montana face to face with several rather serious insect problems. Grasshoppers, mentioned in another part of this report, and numerous other insects became prominent during the year and it was apparent early in the season that this office could do a real service by aiding the farmers to prevent losses.

There has also grown up in recent years a very lively interest in the control of ground squirrels and naturally this office had much to do in directing the campaign against them. In many counties the county agricultural agents cooperated with the farmers in the preparation and distribution of poisoned grain, resulting in the destruction of hundreds of thousands and perhaps millions of squirrels. There can be no doubt that this one piece of work alone saved a great deal of agricultural produce during the year.

In view of the importance of pest control work during the period of the war, the department took steps to organize to meet the demands for assistants. The assistant entomologist, Mr. H. L. Sea-

mans, was placed in the field and kept there through the larger part of the season. Mr. A. L. Strand, who graduated from the entomology course of the college in 1917, was also employed and sent out to direct the farmers in pest control. Two senior students, Mr. Corkins and Mr. King, were also employed in this work at times. As a result, the State was quite well covered and all of the most important outbreaks were visited and the farmers in each instance were helped.

During the year the State entomologist prepared and delivered at the annual meeting of the American Association of Economic Entomologists, at Pittsburgh, Pa., an address entitled "Economic Entomology in the Service of the Nation." This appeared in the Journal of Economic Entomology, Volume 11, pages 16 to 27.

COOPERATION WITH THE EXTENSION SERVICE

The extension service of the college does not employ an entomologist and it has not contributed to the control of insect pests. It has been the policy of the State entomologist's office to cooperate heartily with the extension service and to keep in close touch with the county agricultural agents and with their State leader. Accordingly, we have received many telegrams, letters, and telephone messages from county agents, asking for advice or calling for assistants to be sent to their counties to aid the farmers.

THE GRASSHOPPER OUTBREAK OF 1917

During the fall of 1916 reports reached this office indicating that grasshoppers had been abundant during the summer in the Flathead Indian Reservation in the northern part of Missoula County. County agents of the surrounding counties were warned and steps were taken to do everything possible during the spring to prevent or reduce the damage that might reasonably be expected in 1917. Assistant State Entomologist H. L. Seamans made a thorough survey of the situation in the early spring.

On the occasion of the first trip, in the middle of April, eggs had been found in abundance and on this early date dead grasshoppers of the previous year could be found, as well as evidence of the damage that had been done to winter wheat. Eggs were found in ditch banks, fence rows, especially around alfalfa and clover fields. With many of these eggs were found an abundance of ground beetle larvae and adults (*Harpalus* sp.). The first grasshopper eggs hatched, so far as our records show, about May 15th.

While the grasshopper troubles in 1917 extended scatteringly throughout the State, they centered mainly in an irregular area extending through parts of Missoula, Flathead, and Sanders counties. Roughly speaking, the region affected extended from near the town of Stevensville to Flathead Lake, a distance of about 70 miles. There were more or less grasshoppers throughout this region, but in spots they were very abundant and in some places practically everything green was eaten off. Much more damage would have been done but for the control work which was organized by the county agents and this office in cooperation. The young grasshoppers hatched through a long-drawn-out period and those that hatched first were entirely or quite full grown before the last ones appeared. At no time in the fore part of the season could we tell just how severe the outbreak was to be. As the season advanced and many of the insects had acquired wings the grasshoppers spread out from the more or less restricted areas where they had hatched and the infestation becamè general. It sometimes happened that after the grasshoppers had been killed in a locality others moved in, which made the conditions somewhat discouraging to the farmers. Along with the grasshoppers came a spell of severe dry weather and some crops which had been saved from the insects were afterwards severely injured by lack of moisture. Grasshoppers were also very abundant and some damage was done in the region extending through the western part of Gallatin County and the southern part of Broadwater County. Control operations were carried out here, also.

Extracts from a letter written by Sidney T. Rogers of Three Forks, whose land lies in Broadwater County, are here presented:

"About July the grasshoppers were so thick in my wheat field you could scarcely see wheat heads and were simply destroying it completely. I conferred with our county agent and in response he came with Mr. Seamans and they together constructed a 'hopper machine. I placed my son and daughter in the field on horses attached to each end and they caught twenty-eight (28) gunny sacks of 'hoppers, a fair estimate of 50 bushels.

"I am fully convinced if it had not been for the assistance of Prof. Seamans and Mr. Gordon, onr Broadwater County agent, I would have lost my entire wheat crop of 231 acres."

* * * * * * *

"I am feeding the 'hoppers to our chickens and they have laid

eggs all this fall and to date, and I am fully satisfied they are a good ration for fattening, as they eat them up clean."

WORK WITH THE COUNTY AGENTS

In organizing the control work we cooperated mainly with the county agricultural agents. These men were familiar with the field conditions and with the influential farmers and but for the extension organization we could not have accomplished our work. In the course of our experience it developed that the natural and effective way to accomplish what we were after was to leave the county agents to call all meetings, organize them, and be mainly responsible for their success. Representatives from this office assumed merely an advisory responsibility, delivering lectures and making demonstrations whenever desired and securing information regarding sources of arsenic and other necessary ingredients for the poison formula.

ORGANIZATION OF THE FARMERS

The procedure in organizing control efforts among the farmers was generally to first enter the district and get some information regarding existing conditions, the abundance of grasshoppers, the amount of damage being done, and other points of importance, locally, for use in the work. The county agent then called a meeting of the citizens which was addressed by himself and by the entomologist. The habits of grasshoppers, conditions of the locality so far as we knew them, methods of control, together with a review of the experience in other localities, were discussed and the farmers were organized and asked to form committees. Quite often the committees were made up in part of people from town and in part of farmers for it was recognized that the interests of the town were affected as well as those of the country. Committees for soliciting and for purchasing were appointed and dates for further meetings were fixed. In some instances one committee managed the whole campaign for the community. Dates were appointed when the farmers came together and mixed the poisoned bait. In some instances the poisoned ingredients were delivered before the meeting and in some cases they were brought as the people came to the meeting. The committees sold the poison to the farmers, who took it home and spread it immediately.

One of these "mixing bees" was held on the river bank at Irvine

Flats. A few over ninety men were present on this occasion and about forty-five farm wagons. The whole community was assembled at this point and worked all day preparing the poisoned bran mash which late in the afternoon was shoveled into the back end of the wagons and spread over the valley and foothills. Thirty-five wagons were used in spreading this poison . These were lined up by groups of five and driven over the country in long, broad swaths.

In this neighborhood grasshoppers were incredibly abundant but on returning a few days later relatively few could be found. Such drives as this were organized throughout a territory extending over some 200 square miles, and some 10,000 pounds of white arsenic were used, as well as many carloads of bran and some carloads of lemons and oranges. Tremendous numbers of grasshoppers were killed and the damage that was done in spite of the control efforts was due largely to grasshoppers which hatched later in the same localities or which migrated in from the surrounding foothills and uncultivated lands. The spell of dry weather which occurred at the same time had the effect of causing the grasshoppers to concentrate on low-lying lands which remained green longer and it was quite clear that the grasshoppers moved considerable distances to find such green areas. It was soon found that in some cases a single poisoning of the field or its borders could not be depended upon to protect the crop throughout the season. In some instances, after having poisoned earlier in the season, the farmers resorted to the use of the grasshopper machines to further protect the crops. It was, of course, hoped all the time that rains would come. If it had been known at the outset that rains would be so long delayed, in many instances the farmers would never have made the effort to save the crops. In some cases the efforts were successful and in some they were not, but I believe that the failure was due very largely to the dry weather, which not only itself damaged the crop, but caused concentration of the grasshoppers in the crops.

COOPERATION WITH THE BUREAU OF ENTOMOLOGY

Early in the grasshopper outbreak we entered a cooperative arrangement with and had the assistance of the Bureau of Entomology, U. S. Department of Agriculture. Mr. C. W. Creel, who is in charge of the Forest Grove Entomological Station of the Bureau in Oregon, came to Montana about June 1st with assistants and

remained until August 1st. It was most fortunate that we had this aid from the Federal government, as there was more work than this office could accomplish. We were also benefited by the fact that the Federal government supplied certain funds for the treatment of public lands. In many instances the farmers were not willing to treat their own lands unless the public lands in the vicinity might also be treated, thus preventing the entrance of grasshoppers after the farms had once been cleaned up. The assistants with Mr. Creel were Mr. Rockwood and Mr. Taylor.

KINDS OF GRASSHOPPERS IN THE OUTBREAK

From the fragments of grasshoppers which were found in April, which were the remains of those present the year before, it became evident that the species concerned was the well-known lesser migratory locust, *Melanoplus atlanis* Riley, or a closely related species, and from the nymphs which were found during the early part of the season we had further evidence that the species concerned belonged in the *atlanis* group. When adult grasshoppers, however, began to emerge about July 8th, it was learned that they more closely resembled the old Rocky Mountain migratory locust which fifty years ago wrought extensive damage in the northwestern States. As more and more of the insects reached the adult condition it was evident that the great mass of them belonged to this form. Accordingly, large numbers of the specimens were taken for future study.

We cannot say definitely at this time just what species this grasshopper is. However, for present purposes it is enough to say that, if it is not the Rocky Mountain migratory locust, it is very closely related to it. It is a long-winged form and a good flier. We did not witness any extensive migrations of the species, but such migrations were reported by the residents.

It is of much importance to determine as soon as possible whether or not it is the destructive species of fifty years ago for it is desirable to know whether potentially this grasshopper is as injurious as that one. Accordingly, an effort will be made to determine more closely the specific identity of this insect.

NATURAL ENEMIES

In our journeyings through the region affected by this grasshopper we watched for the parasites which might be of service in

holding the outbreak in check and on July 8th many flesh flies (*Sarcophaga*) were seen and from this day on, periodically, they were found in great abundance wherever the grasshoppers occurred. Large numbers of dead grasshoppers were found on the ground and many examinations revealed that the maggots were in the grasshoppers in great numbers. There is much reason to believe that, if this outbreak fails to develop into a seriously extensive one, it will be due to these flies which appeared in innumerable numbers, depositing young maggots on the adult insects.

EGGS IN THE FALL

Assistants were sent to the region in the fall who made thorough surveys for evidence of egg-laying, for it was desired to know if we were to have a recurrence of the grasshopper outbreak in 1918. Through several days of searching no grasshopper eggs whatever were found and from this fact it is hoped that there will not be any serious trouble next season.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

BULLETIN NO. 125 MARCH, 1918

Fourth Annual Report of the Montana Grain Inspection Laboratory

BY

ALFRED ATKINSON, *Director of Laboratory*

E. W. JAHNKE, *Superintendent*

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

NOTICE.—The bulletins of the Experiment Station will be mailed free to any citizen of Montana on request. Please state whether all the publications are desired as issued or only those specified. Give name and address plainly. All communications should be addressed to the Montana Experiment Station, Bozeman, Montana.

Fourth Annual Report of the Montana Grain Inspection Laboratory

The State Legislature of 1913 made provision for the establishment and maintenance of a State Grain Laboratory to be located at the Agricultural Experiment Station, Bozeman. The purpose of the laboratory was to study the milling and baking qualities of Montana-grown wheats and to make germination and purity determinations on seed samples sent in as well as those collected by official inspectors.*

In 1917 the State Legislature authorized the name of the laboratory to be changed to the Montana Grain Inspection Laboratory. With this change provision was made to establish the true grade and determine the proper dockage on grain samples sent in for that purpose. The Montana grain inspection laws for the grading of wheat provide that the grain grades established by the United States Department of Agriculture shall be accepted as the official grades within this State.**

THE YEAR'S WORK

The following is a report of the year's work from October 1, 1916, to September 30, 1917.

That the work of the laboratory is educational is shown by the increasingly large number of samples voluntarily sent in, indicating that farmers are growing in appreciation of the fact that good seed is one of the first requisites of good farming. The work for 1916-17 included germination and purity tests made on 6,668 samples of seed voluntarily sent in by farmers and seedmen and on 2,082 samples officially collected. This was an increase of

*A copy of the laws establishing the laboratory and regulating the sale of agricultural seeds, together with rules and regulations for sampling and sending in grain samples to the laboratory, is contained in Circular 30 and will be sent to any address upon request.

**A copy of the grades, together with rules and regulations governing the taking of samples of grain for grading, will be sent to any person upon request.

286 per cent over the samples tested in 1913-14, 236 per cent over 1914-15, and 73 per cent over 1915-16.

The work accomplished during the year may be briefly summed up as follows:

1. The determination of 6,668 purity and germination tests of seed samples voluntarily sent to the laboratory.

2. The determination of 2,082 purity and germination tests of seed samples officially collected.

3. A continuation of the study of the seed value of frosted wheat samples.

4. A continuation of the study of the germination of seeds at different periods after they have been harvested.

5. Cooperative purity and germination tests with the Association of Official Seed Analysts of North America.

6. A continuation of milling and baking studies of Montana-grown wheats.

7. The determination of grade and dockage on samples of wheat sent to the State Grain Inspection Laboratory.

Table I shows the source by counties of the different seed samples sent in during the past four years. Several counties show very striking increases in the total of different crop seeds sent in. Custer county, for instance, shows an increase of 65.6 per cent over the number sent in during 1915-16; of the 684 samples received this year, 448 were alfalfa and 149 were corn. Fergus County showed an increase of 177 per cent over 1915-16: Gallatin County, 52 per cent; and Lewis and Clark County the very marked increase of 351 per cent, 540 of the samples from this county being vegetables and 697, flowers. Rosebud County sent in an even 1700 samples, of which 1572 were corn. Sheridan County showed an increase from 74 samples in 1915-16 to 117 in 1916-17, 58 per cent; the majority of these samples were wheat and flax. The great increase in the total number of samples received was the outstanding feature of the year's work.

The number of samples received from the farmers and from the dealers has greatly increased. The percentage of the total number of samples received from the farmers shows a steady increase each year while the percentage of the total received from the dealers is annually decreasing. In 1913-14 dealers sent in 40.8 per cent and farmers 59.2 per cent of the total number of

TABLE I. SHOWING THE NUMBER OF SAMPLES OF SEEDS RECEIVED FROM THE DIFFERENT COUNTIES

County	1916-17	1915-16	1914-15	1913-14
Beaverhead	26	34	11	33
Big Horn	57	3	15	9
Blaine	82	132	96	71
Broadwater	20	7	2	9
Carbon	25	34	13	23
Cascade	142	158	81	35
Chouteau	58	62	48	52
Custer	684	413	302	154
Dawson	116	125	93	91
Deer Lodge	4	0	3	40
Fallon	23	55	38	89
Fergus	302	109	19	35
Flathead	55	57	3	25
Gallatin	741	487	302	360
Granite	6	2	11	3
Hill	188	128	194	225
Jefferson	21	10	3	8
Lewis and Clark	1,448	321	165	134
Lincoln	0	2	0	12
Madison	12	8	10	13
Meagher	21	50	14	19
Mineral	1	0	0	0
Missoula	71	117	24	8
Musselshell	55	120	72	145
Park	79	115	80	68
Phillips	4	0	0	0
Powell	27	8	3	17
Ravalli	43	30	2	0
Richland	36	26	14	10
Rosebud	1,700	930	188	126
Sanders	4	5	5	5
Sheridan	117	74	11	11
Silver Bow	8	25	24	21
Stillwater	10	27	13	13
Sweet Grass	18	13	0	26
Teton	86	84	77	67
Toole	22	7	0	0
Valley	74	97	82	62
Wibaux	14	3	0	0
Yellowstone	192	254	141	160
Unknown	20	24	....	39
Out of State	56	56	53	48
Total	6,668	5,035	2,570	2,266

samples received; in 1914-15 dealers sent in 39.1 per cent and farmers 60.9 per cent; in 1915-16 dealers sent in 26.3 per cent and farmers 73.7 per cent; while in 1916-17 dealers sent in but 20.88 per cent and farmers 79.12 per cent. It is evident that the farmers realize the value of having their seed grain tested and each year they are sending in more samples.

PURITY OF GRAINS AND GRASSES

Table II shows the number of samples of grains and grasses received and the average percentage of pure seed in each. In general the majority of our coarse grains and grasses run very low in their percentage of pure seed and most of them are below the United States Standard.

There was a great increase in the number of such samples received this year and there was also a great increase in the percentage of impurities found. These impurities consisted of dirt, chaff, sticks, weed seeds, and so forth. By planting seed including such material the grain growers of Montana are annually losing thousands of dollars. Before buying grain or grass seed, samples should be sent to the Grain Laboratory to be tested. If the percentage of impurities is high or if weed seeds are numerous or of a serious nature, it it not advisable to use such seed for the next year's crop.

TABLE II. AVERAGE PURITY OF GRAINS AND GRASSES.

Seed	Number of samples	Purity, 1916-17 (per cent)	Purity, 1915-16 (per cent)	U. S. standard (per cent)	Above standard 1916-17	Below standard 1916-17
Wheat	1,086	92.39	93.64	99	116	970
Oats	225	96.25	96.88	99	35	190
Flax	183	94.38	95.36	....	....	....
Barley	82	94.88	90.47	99	10	72
Timothy	108	93.39	95.18	98	46	62
Millet	42	90.26	95.56	99	6	36
Rye	23	90.57	90.45	99	1	22
Brome-grass	26	86.30	87.96	90	15	11
Rape	7	97.95	99.11	....	....	....
Sudan grass	16	95.92	94.14	....	....	....
Spelt	12	86.21	94.62	....	....	....
Blue-grass	9	85.22	84.98	90	1	8
Rye-grass	8	87.93	92.04	....	....	....
Wheat-grass	18	76.16	70.92	....	....	....
Vetch	4	98.38	96.22	....	....	....
Buckwheat	7	97.02	97.98	99	0	7
Orchard-grass	2	87.58	86.72	....	....	....
Redtop	5	95.20	88.50	....	....	....

PURITY OF ALFALFA AND CLOVER SAMPLES

Table III shows the number of samples of alfalfa and clovers received and compares the average purity tests for this year with those for the preceding year and with the United States Standard. The percentage of pure seed in 942 samples of alfalfa averaged 96.16; 678 of these samples were above the United States Standard while only 264 were below. This shows that Montana-grown alfalfa seed is comparatively clean.

The clover samples in general were comparatively low in their percentage of pure seed.

TABLE III. AVERAGE PURITY OF ALFALFA AND CLOVER

Seed	Number of samples	Purity, 1916-17 (per cent.)	Purity, 1915-16 (per cent.)	U. S. standard (per cent.)	Above standard 1916-17	Below standard 1916-17
Alfalfa	942	96.16	93.64	98	678	264
Red clover	95	84.46	91.91	98	25	70
Sweet clover	76	93.08	96.67	....	....	....
Alsike clover	30	86.91	93.50	95	13	17
White clover	7	93.61	90.54	95	3	4
Average		90.84	93.23			

DISTRIBUTION OF WEED SEEDS

Table IV gives the percentage of samples in which seeds of the most serious weeds have been found during the past two years. Outside of the great increase in the number of samples received, the increase in the number of weed seeds found is the outstanding feature of this year's work. Weed seeds are rapidly spreading to all parts of the State and greater care should be taken in the selection of new seed.

Some very marked increases in the percentage of weed seeds were found in the crop seeds examined. Of those found in wheat, we note that in every case the percentage of weed seeds listed is higher this year than for the preceding years. In this list we find some of our worst enemies, such as mustard, dock, wheat-grass, wild oat, and so forth. In oats, barley, and flax, we note

TABLE IV. SHOWING THE PERCENTAGE OF THE SAMPLES EXAMINED IN WHICH SEEDS OF THE DIFFERENT WEEDS ARE FOUND

Common name	Botanical name	Alfalfa		Red clover		Sweet clover		Timothy	
		1915-16	1916-17	1915-16	1916-17	1915-16	1916-17	1915-16	1916-17
Dodder	Cuscuta spp.	18.72	28.13	....	....	....	....	....	....
Mustard	Brassica spp.	17.16	10.19	10.52	10.63	3.44	19.73	22.22	17.59
Lamb's-quarters	Chenopodium album	76.96	45.75	65.79	82.97	81.03	59.21	71.71	68.51
Russian thistle	Salsola pestifer	62.14	40.55	21.04	6.38	34.48	23.68	....	....
Sweet clover	Melilotus spp.	38.74	40.55	....	12.76	....	....	....	....
Green foxtail	Chaetochloa viridis	32.24	38.75	44.73	35.10	10.32	34.21	5.05	3.70
Pigweed	Aramanthus retroflexus.	19.50	21.33	....	22.34	13.76	21.05	8.08	17.59
Curled dock	Rumex crispus	8.58	14.54	28.94	18.08	22.36	26.32	17.17	25.92
Plantain	Plantago spp.	10.66	12.10	52.65	10.63	....	....	28.28	45.37
Gumweed	Grindelia squarrosa	18.20	10.50	10.52	1.06	25.80	13.16	15.15	8.33
Wild buckwheat	Polygonum convolvulus.	25.48	27.92	18.41	13.82	22.43	19.73	....	1.85
Ragweed	Ambrosia artemisiifolia	....	0.43	21.04	6.38	....	....	....	....
Sheep sorrel	Rumex acetosella	....	0.63	21.04	23.40	....	....	14.14	26.85
Smartweed	Polygonum persicara	....	4.98	18.42	12.76	....	....	....	....
Fanweed	Thlaspi arvense	....	0.54	5.26	3.19	....	....	16.16	10.18
Sunflower	Helianthus spp.	....	11.25	....	6.38	22.36	17.10	....	....
Wheat-grass	Agropyron spp.	....	11.89	....	....	34.40	10.52	14.14	19.44
Five-finger	Potentilla spp.	....	0.31	....	....	....	1.31	55.55	60.18
Peppergrass	Lepidium apetalum	....	0.95	....	4.25	....	....	47.47	40.74
Shepherd's purse	Bursa bursa-pastoris	....	0.10	....	....	....	....	42.42	21.29
Wild oat	Avena fatua	....	0.53	....	6.38	....	5.26	....	1.85
False flax	Camelina sativa	....	13.68	....	7.44	....	5.26	34.34	23.14
Cow cockle	Vaccaria Vaccaria	....	4.88	....	....	....	....	....	....
Roadside thistle	Carduus discolor	....	0.84	....	5.31	....	11.84	....	....
Corn cockle	Agrostemma githago	....	....	....	....	....	....	....	....
Marsh elder	Iva xanthiifolia	....	5.09	....	8.51	....	15.78	....	....
Hare's-ear mustard	Conringia orientalis	....	5.72	....	....	....	....	....	....
Yellow foxtail	Chaetochloa glauca	....	1.38	....	....	....	....	....	....

TABLE IV (Continued). SHOWING THE PERCENTAGE OF THE SAMPLES EXAMINED IN WHICH SEEDS OF THE DIFFERENT WEEDS ARE FOUND

Common name	Wheat 1915-16	Wheat 1916-17	Oats 1915-16	Oats 1916-17	Barley 1915-16	Barley 1916-17	Flax 1915-16	Flax 1916-17	Millet 1915-16	Millet 1916-17
Dodder	....	....	....	....	....	....	....	1.63	....	....
Mustard	13.46	16.75	18.92	20.88	17.02	17.07	28.80	28.96	33.28	26.19
Lamb's-quarters	13.46	20.74	17.63	25.33	19.14	18.29	30.40	32.24	33.28	25.57
Russian thistle	4.18	7.97	....	9.77	3.18	4.87	31.20	51.91	22.88	10.92
Sweet clover	....	1.18	....	4.88	....	....	....	1.64	....	7.14
Green foxtail	1.10	1.33	2.15	0.88	....	4.87	8.00	8.74	58.24	66.66
Pigweed	3.08	4.78	1.29	....	....	2.43	14.40	13.20	16.64	14.28
Curled dock	0.66	0.69	2.58	1.77	....	2.43	....	1.64	....	4.76
Plantain	0.66	0.79	....	....	....	....	....	....	....	1.92
Gumweed	0.22	0.53	....	....	....	....	....	....	....	....
Wild buckwheat	26.27	28.05	18.92	27.55	25.53	32.92	16.00	21.31	8.32	23.80
Ragweed	0.88	1.06	....	....	....	....	....	1.09	10.40	7.14
Sheep sorrel	....	....	....	....	....	....	....	....	....	....
Smartweed	....	1.06	....	....	....	....	....	6.01	18.72	....
Fanweed	3.52	4.10	2.15	4.00	5.31	6.09	....	....	....	....
Sunflower	7.94	15.02	11.62	17.33	7.42	6.09	10.40	9.84	18.72	7.14
Wheat-grass	4.84	16.41	6.45	8.88	....	3.65	9.60	18.57	....	7.14
Five-finger	....	0.13	....	....	....	....	....	....	....	....
Peppergrass	0.66	1.06	....	1.77	....	1.21	....	....	....	....
Shepherd's purse	....	....	....	0.44	....	1.21	....	0.60	....	....
Wild oat	20.97	26.19	40.69	45.33	38.29	34.14	8.00	8.19	6.24	14.28
False flax	3.74	4.92	2.58	4.88	2.12	1.21	26.40	22.95	....	4.76
Cow cockle	17.21	17.67	8.27	7.55	....	6.09	2.40	10.92	6.24	7.14
Roadside thistle	1.10	1.46	....	....	....	....	....	0.54	....	....
Corn cockle	0.88	3.05	1.29	1.33	....	1.21	....	....	....	....
Marsh elder	1.10	1.33	....	2.66	7.42	1.21	....	....	....	2.38
Hare's-ear mustard	12.58	14.09	....	8.44	2.12	9.76	....	24.04	6.24	7.14
Yellow foxtail	....	....	....	....	....	....	....	....	29.12	14.28

wild buckwheat, fanweed, wild sunflower, wild oat, wheat-grass, false flax, and cockles.

In alfalfa, dodder showed a decided increase. In 1913 only 11.02 per cent of the alfalfa examined showed the presence of dodder; in 1914, 14 per cent; in 1915, 18.72 per cent, and in 1916, 28.13 per cent. As dodder is considered one of our five worst weeds, great care should be taken not to plant alfalfa containing this seed. There was also a rapid increase in the percentages of sweet clover, green foxtail, pigweed, curled dock, wild buckwheat, wild sunflower, wheat-grass, false flax, and hare's-ear mustard found in alfalfa. It is worth noting that the percentages of wild mustard and Russian thistle have decreased considerably since last year.

In red clover the percentages of lamb's-quarters, sweet clover, pigweed, wild sunflower, false flax, and marsh elder have increased very rapidly. In sweet clover, wild mustard, green foxtail, curled dock, roadside thistle, and marsh elder have shown a decided increase. In timothy, pigweed, curled dock, sheep sorrel, wheat-grass, and five-finger show increased percentages.

Due to the scarcity of clean seed this year, especially of the coarser grains, every farmer ought to be urged to find out definitely the purity of his seed before planting. Seedsmen should see that the seeds they offer for sale are clean and free from weed seeds. Samples should be sent to the State Grain Inspection Laboratory at the Agricultural Experiment Station, Bozeman, and reports on the purity as well as on the germination will be sent promptly, free of charge. If the test shows that the seed is below the standard, have it recleaned before seeding.

AVERAGE GERMINATION OF GRAINS AND GRASSES

Table V shows the number of samples of the leading grains and grasses received and the average percentage of germination. Excepting for the samples of oats, rye, Sudan grass, spelt, vetch, and redtop, the percentages for 1916-17 are higher than those for 1915-16, but only in the case of vetch is the difference enough to be significant. The tests of corn and wheat were especially high. Of 1893 samples of corn, 1663 were above the United States Standard. The vitality of any seed is a very important factor in secur-

ing a good stand of any given crop. As the germination power of these crop seeds is easily injured by unfavorable weather conditions, it is very important that they be tested before planting.

TABLE V. AVERAGE GERMINATION OF GRAINS AND GRASSES

Seed	Number of samples	Germination, 1916-17 (per cent)	Germination, 1915-16 (per cent)	U. S. standard (per cent)	Above standard 1916-17	Below standard 1916-17
Corn	1,893	83.70	79.89	85–90	1,663	230
Wheat	1,086	94.20	93.29	90–95	917	169
Oats	225	82.19	88.06	90–95	109	116
Flax	183	94.15	94.05	....	....	....
Barley	82	91.09	85.82	90–95	40	42
Timothy	108	92.26	91.49	85–90	95	13
Peas	208	90.42	90.36	93–98	66	142
Millet	42	89.73	87.10	85–90	31	11
Rye	23	91.40	91.69	90–95	12	11
Brome-grass	26	86.48	68.65	75–80	20	6
Rape	7	93.00	92.50	90–95	3	4
Sudan grass	16	72.28	73.77	....	....	....
Spelt	12	86.75	87.10	....	....	....
Blue-grass	9	78.55	56.90	45–50	9	0
Rye-grass	8	91.68	42.87	....	....	....
Wheat-grass	18	77.98	24.66	....	....	....
Vetch	4	72.57	93.25	....	....	....
Buckwheat	7	94.86	93.00	90–95	5	2
Orchard-grass	2	80.25	71.50	....	....	....
Redtop	5	90.11	90.50	....	....	....

TABLE VI. AVERAGE GERMINATION OF ALFALFA AND CLOVER

Name of seed	Number of samples	Germination, 1916-17 (per cent)	Germination, 1915-16 (per cent)	Hard seeds (per cent)	U. S. standard (per cent)	Above standard 1916-17	Below standard 1916-17
Alfalfa	942	92.13	89.11	19.18	85–90	777	165
Red clover	94	89.37	92.38	16.90	85–90	52	42
Sweet clover	76	87.03	85.72	20.36	....	....	....
Alsike clover	30	92.33	91.32	10.43	75–80	26	4
White clover	7	89.88	85.13	22.80	75–80	6	1

AVERAGE GERMINATION OF ALFALFA AND CLOVERS

Table VI shows the number of alfalfa and clover samples received and the average percentage of germination. Except for the samples of red clover, this table shows that a great majority of the germination percentages were above the United States Standard. The vitality of Montana-grown alfalfa and clovers is good.

AVERAGE GERMINATION OF VEGETABLE SEEDS

Table VII shows the number of vegetable seed samples received and the average percentage of germination. Th total number of samples received in 1917 was 622 as compared with 214 in 1916. The average percentages shown are not especially high. As vegetable seeds do not keep their vitality as long as a great number of other seeds, this may indicate that many of the samples were from old stock.

ADMIXTURE OF OTHER CROP SEEDS

Table VIII gives the number of samples of seed of our five most common crops and the percentage of wheat, oats, barley, rye, and flax found in each. From the table it is evident that the percentage of these mixtures is very high. The crop harvested from planting seed containing only a trace of such mixtures is apt to contain a very large percentage of them. When planting any of these grains, farmers ought to make an effort to plant only pure seed. Samples should always be tested before the crop is planted. Pure seed will always be sold at a premium.

INSPECTION

Besides arranging for the determination of the purity and vitality of seed samples voluntarily sent to the laboratory, the Montana seed laws also provide for the inspection of "agricultural seed" sold or offered for sale in this State at such time and place as the director may desire. Agents may be appointed to make such inspections and to collect samples of any lot or lots of seed desired. This is the first year that we have officially collected such samples. A total of 2,082 samples was taken, brought to the laboratory, and tested both for purity and germination. Of the total collected, 927 samples were taken from lots where one pound or more of agricultural seed was offered for sale. The remaining 1,155 samples were mostly of vegetables and flowers put up in small packets.

TABLE VII. AVERAGE GERMINATION OF VEGETABLE SEEDS

Name of seed	Number of samples	Germination, 1916-17 (per cent)	Germination, 1915-16 (per cent)	U. S. standard (per cent)	Above standard 1916-17	Below standard 1916-17
Asparagus	9	94.27	80.00	80–85	9	0
Beans	40	83.48	94.39	90–95	15	25
Beets	34	79.17	76.60	....	....	....
Broccoli	3	59.50	....	....	....	....
Brussels sprouts	2	73.00	76.16	....	....	....
Cabbage	32	81.68	80.66	90–95	6	26
Carrots	15	81.70	72.54	80–85	6	9
Cauliflower	11	80.95	79.61	....	....	....
Celery	22	77.73	69.00	60–65	17	5
Corn salad	2	74.25	....	....	....	....
Cress	2	77.50	73.50	85–90	1	1
Cucumber	34	80.62	93.11	85–90	17	17
Endive	11	61.95	....	....	....	....
Egg plant	2	61.25	65.70	75–80	0	2
Gourds	12	66.66	....	....	....	....
Kohlrabi	6	76.08	....	....	....	....
Kale	4	93.50	....	....	....	....
Leek	2	46.75	74.12	....	....	....
Lettuce	35	84.60	96.43	85–90	22	13
Mangels	12	65.55	....	....	....	....
Mustard	5	85.20	....	....	....	....
Muskmelon	49	90.16	80.75	85–90	33	16
Okra	7	61.35	....	80–85	0	7
Onion	39	80.29	86.13	80–85	24	15
Parsnip	4	66.75	33.34	70–75	2	2
Parsley	7	73.85	57.33	70–75	4	3
Pepper	6	55.80	53.56	....	....	....
Pumpkin	30	85.60	92.50	85–90	16	14
Radish	39	90.68	86.13	90–95	26	13
Rhubarb	11	88.18	....	....	....	....
Rutabaga	8	85.37	90.50	....	....	....
Salsify	1	90.50	....	75–80	1	0
Spinach	6	81.00	....	80–85	3	3
Squash	40	83.17	81.87	85–90	16	24
Tomato	39	75.87	88.00	85–90	11	28
Turnip	16	88.40	91.50	90–95	8	8
Watermelon	25	81.98	88.88	85–90	10	15

TABLE VIII. PERCENTAGE OF SAMPLES OF THE FIVE MOST COMMON CROPS CONTAINING SEEDS OF WHEAT, OATS, BARLEY, RYE, AND FLAX

Seed tested	Number of samples tested	Percentage of samples tested containing				
		Wheat	Oats	Barley	Rye	Flax
Wheat	1,086		61.41	67.93	60.87	28.17
Oats	225	41.09		73.07	30.43	17.12
Barley	82	28.45	58.53		26.08	1.10
Rye	23	3.06	0.97	3.84		1.10
Flax	183	7.58	9.75	7.69	8.69	

Of the 927 samples, only 16.67 per cent were correctly labeled. This leaves a total of 83.33 per cent with incorrect or no labels; that is, not containing the name of the seed, the percentage of foreign and other material, the percentage of pure seed, the percentage and date of germination test, and name and address of seedsman. This shows considerable room for improvement. It is hoped that in the future sellers of agricultural seeds will pay more attention to the accurate labeling of their seeds.

We hope to continue the inspection work during 1917-18, publishing the names of seed firms from which such samples are taken and comparing the figures given on their labels with the results secured by the seed laboratory. It will then be possible for the buyers of seeds to follow the records of companies, and the publicity should be of material assistance in improving the quality of seed offered for sale.

The samples officially collected were taken from the regular stock of seed firms. The number of samples from each county follows:

Blaine	109	Fergus	40
Broadwater	12	Flathead	248
Cascade	160	Gallatin	35
Chouteau	83	Hill	180
Custer	167	Lewis and Clark	83
Dawson	108	Missoula	226

Park	94	Rosebud	56
Powell	2	Silver Bow	29
Ravalli	81	Teton	4
Richland	1	Valley	111
Yellowstone	253		

These samples were divided among the different crops as follows:

Alfalfa	138	Millet	63
Barley	30	Peas	188
Alsike clover	30	Rye	3
Red clover	49	Spelt	4
Sweet clover	55	Herbs	4
White clover	38	Timothy	65
Corn	209	Wheat	50
Flax	15	Vegetables	944
Oats	28	Grasses	142
Flowers	27		

In most instances the samples of grasses and grains collected from seed firms show a higher percentage of purity than those voluntarily sent in. Of the nineteen crop seeds mentioned, the average purity tests of wheat, Sudan grass, blue-grass, buckwheat, orchard-grass, and redtop are the only ones that show lower percentages than the averages of samples of the same crops voluntarily sent in. This shows that seed dealers throughout the State are handling a higher grade of coarse grains than that put on sale by the general public. Most seed houses have better facilities for cleaning such grain than the average farmer has.

In every case the average purity of the alfalfa and clovers handled by seed firms is of a higher percentage than the average of those voluntarily sent in. The seed dealers are evidently handling a very high grade of Montana-grown alfalfa and clovers.

The average percentage of germination for the majority of the coarse grains officially collected is considerably above that for those voluntarily sent in. However, some of the samples of grass seed officially collected show a noticeably lower average than those voluntarily sent in.

In all cases the average percentage of germination of alfalfa and clover seeds was higher for the collected samples than for those

sent in. These percentages are very high and the number above the government Standard speaks well for the quality of this class of seed handled by firms throughout Montana.

The samples of vegetable seeds officially collected showed an average percentage of germination considerably below that of the samples sent in. As the call for such seeds throughout the State has not been as great as for coarse grains, the samples collected were drawn mostly from old stock, which accounts for their low percentage of germination.

As long as the average purity tests of most of the samples collected were above the average of those sent in, we would naturally expect to find the weed seed content lower in the collected samples. This was true except in a few cases.

With the exception of the vegetable seeds, all samples officially collected show a comparatively high percentage of both purity and germination. Therefore we may say that the seed firms throughout the State are to be commended for the high grade of seed they have been offering to the trade.

SEED VALUE OF FROSTED WHEAT

Farmers often have the opinion that frosted wheat is of little or no value for seeding purposes. From tests carried on at the laboratory it would seem that ordinary frost injury does not render the seed entirely worthless for seeding purposes. Usually frost injures the outer coat or bran of the berry and the germ remains unharmed. In many samples that showed results of severe frost injury the germination was very slow but plants grown from such seed were apparently as strong and produced as good seed as the unfrosted berries.

These results are brought out in Table IX, the work of which was carried out in 1916. Field tests were made to compare the producing power of frosted and unfrosted kernels. The plan followed in getting the kernels for this test was to use thirty-two wheat samples, showing a large percentage of frosted kernels, that were sent to the laboratory for testing. Each sample was carefully divided into two parts, one containing only kernels showing frost injury and the other only kernels showing absolutely no frost injury. An equal number of frosted and unfrosted kernels were then planted in rows side by side. This made two rows from each sample, or

sixty-four rows from thirty-two wheat samples in the test.

The results as given in this table show a slightly lower field germination but a greater number of heads per row and thus a higher yield from the frosted kernels. The difference is not great enough to be very significant, yet it shows that kernels damaged by frost are not necessarily worthless for seed.

This year thirty-six samples of frosted and unfrosted wheat were collected in the same way as those for 1916. Because of the very dry weather conditions the grain did not make sufficient growth to mature so it was impossible to compare results on field tests. However, laboratory tests of these samples showed that the average percentage of germination of the frosted wheat in the sixty-six samples was 77 as compared with 93 per cent for the unfrosted. It should be understood that grain may be entirely destroyed by frost so far as its seed value is concerned, but this test suggests that all grain need not be discarded for seed because it shows frost injury. The only safe plan is to have it tested before deciding either to use or to discard it.

TABLE IX. SEED VALUE OF FROSTED WHEAT

	Laboratory tests—1917			Field tests—1916		
Condition of seed	Number of samples	Field germination (per cent)	Average number of heads per row	Grain per row (grams)	Number of samples	Average germination (per cent)
Frosted	32	75	1,525	1,457	66	81
Unfrosted	32	78	1,509	1,375	66	93

GERMINATION OF GRAIN AT DIFFERENT PERIODS AFTER THRESHING

Work on the germination of seed grain at different periods after threshing was carried on again this year. Samples of wheat, oats, and barley were collected from several localities throughout the State. After being thoroughly mixed, these samples were stored in a dry place in the laboratory. Germination tests were started each week. Samples that showed a very low and slow germination the first week after being threshed usually grew very rapidly at the end of two months.

Table X shows the results of these tests as well as of those carried on in 1915 and 1916.

TABLE X. GERMINATION OF GRAIN AFTER THRESHING

	Winter wheat 1915	1916	1917	Spring wheat 1916	1917	Oats 1915	1917	Barley 1915	1917
Number of tests	7	14	23	12	19	5	16	4	11
Germination percentage one week after threshing	53	8	27	18	31	15	21	66	43
Germination percentage one month after threshing	79	66	70	75	81	88	57	86	77
Germination percentage two months after threshing	96	99	93	90	94	96	83	95	89

It is generally understood that newly threshed grain must be given a resting stage or curing period before it will grow readily. This point is clearly brought out in Table X. Winter wheat this year was very scarce throughout the State and a great deal of this year's crop had to be planted immediately after being threshed. Many samples tested that were not included in the table showed a very low percentage of germination and in some instances more than twice the ordinary amount of grain had to be sown. Of twenty-three samples of winter wheat tested, the average percentage of germination at the end of the first week after threshing was but 27. At the end of the first month it was 70 per cent and at the end of two months, 93 per cent. The results obtained with spring wheat, oats, and barley were similar to those with winter wheat. When planting newly threshed grain, it is always wise to first have it tested in order to know the correct amount to sow.

WORK WITH THE ASSOCIATION OF OFFICIAL SEED ANALYSTS

The Montana Laboratory again this year, in cooperation with the Association of Seed Analysts of North America, conducted seed referee work in making germination and purity tests. The object of this work is to ascertain as far as possible the methods employed by different seed laboratories in making these tests and to compare the results obtained on the same lots of seed. This ultimately will bring about more uniform methods in testing seeds and more uniform seed laws.

The Association is composed of the seed laboratories of the various States and each year one of these laboratories is selected as referee. This year samples of different kinds of seeds were sent out by the referee and thirty-three laboratories sent in reports. The Montana laboratory again made a very creditable showing. For results obtained in germination work it was grouped among the ten highest. In several instances our tests averaged from one to two per cent higher than those made by the referee.

For results obtained in making purity tests, the referee stated, "Your results were found to be very close to the correct ones and compared favorably with those of the other states." One of the purity tests of red clover made by the Montana laboratory showed a difference of but eight-hundredths of one per cent from the referee's results and but four-hundredths of one per cent from the average of all the laboratories.

MILLING AND BAKING STUDIES OF MONTANA-GROWN WHEATS

Because of lack of space and the great increase in the number of purity and germination tests asked for, it has been impossible to carry on the milling and baking tests of Montana-grown wheats as extensively as we wished.

At the present time we have more help and ample room has been furnished us in which to conduct our milling and baking tests. Several interesting experiments have already been started.

DETERMINATION OF GRADE AND DOCKAGE

March 31, 1917, marked the date on which the official grades for wheat were issued. The Federal standards for winter wheat went into effect July 1st and for spring wheat August 1, 1917. Since that time the grades of over five hundred samples have been determined at the Montana Grain Inspection Laboratory. Dockage tests, test weights, moisture tests, and so forth were also made on these samples sent in. The results of this work will be published separately at the end of the fiscal year.

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UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION
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Sixteenth Annual Report of the State Entomologist of Montana

False chinch bug (*Nysius ericae* Schill)

BY
R. A. COOLEY

Sixteenth Annual Report of the State Entomologist of Montana

NOTES ON INSECT PESTS OF 1918

THE MITES AND TICKS (ACARINA)

Red Spider (*Tetranychus bimaculatus* Harvey).—Red spiders were reported from several counties as injuring the foliage of raspberries and currant bushes.

Pear-Leaf Blister-Mite (*Eriophyes pyri* Pagnat).—Fruit growers in the Bitter Root district each year report that the blister-mite is their biggest problem in insect control. While this mite was present in smaller numbers in 1918 than for several years previously, yet considerable injury was done in orchards that did not receive the lime-sulphur spray early in the spring.

CRICKETS AND GRASSHOPPERS (ORTHOPTERA)

Black Cricket (*Gryllus assimilis* Stew.).—During the late summer and early fall the common black cricket became so abundant in parts of Big Horn County that it attracted considerable attention from farmers, who feared the destruction of their crops. In some localities the ground was black with crickets. Flax and oats were badly injured by their eating into the boll and the kernel. This is the first report of serious cricket injury that has come to the State entomologist's office.

Coulee Cricket (*Peranabrus scabracollis* Thom.).—This large, repulsive-looking insect was again present in injurious numbers near Ronan on the Flathead Indian Reservation. Large, migrating armies of what was probably the same species were reported along the southern boundary of Gallatin County.

Grasshoppers (*Melanoplus* sp.).—Grasshopper injury was much less severe than in 1917. Great damage was done locally on many farms but no outbreaks occurred over large areas.

Yellow-Winged Grasshopper (*Camnula pellucida* Scud.).—

This species was unusually abundant in the upper Bitter Root valley and in many local outbreaks in other parts of the State. In no instance, however, was it reported as migrating.

THE TRUE BUGS (HEMIPTERA)

False Chinch Bug (*Nysius ericae* Schill).—Farmers have repeatedly mistaken this bug for the chinch bug and its unusual abundance during the past season caused considerable alarm. Letters and telegrams were received, stating that chinch bugs were invading grain fields, but in every case the false chinch bug was the cause of the scare. No damage to grain crops was found but gardens were very badly injured.

Cabbage Aphis (*Aphis brassicae* L.).—Cabbages, rutabagas, and rape in all parts of the State suffered from the attacks of the cabbage aphis, which was more abundant than for several years. Spraying with Black Leaf 40 and soap will control this serious pest of garden and field crops.

Elm Gall Louse (*Schizoneura americana* Riley).—Elm trees in all parts of the State suffered from the attacks of this pest. In the Gallatin Valley the returning fall migrants from the service-berry swarmed to the elm trees by the millions, indicating that the injury will be worse than ever next year.

Fall-Grain Aphis (*Macrosiphum* sp.).—Many letters were received during the fall months concerning an aphid which covered the heads of grain at harvest time. This plant louse attracts attention each fall but apparently appears too late to injure the crop of the present year and does no appreciable damage to fall-seeded grain.

Sugar-Beet Root-Louse (*Pemphigus betae* Doane).—This was not as abundant as usual, but nevertheless caused considerable damage in the beet-growing sections of the State. Experiments conducted in the Yellowstone Valley show that the injury can be very greatly reduced by frequent irrigations.

Green Apple Aphis (*Aphis pomi* De G.).—This aphis was present in considerably less than normal abundance.

Grain Root Aphis (*Forda occidentalis* Hort.) was reported from many parts of the State as abundant on roots of small grains and grasses. No proof of its injuring grain has been established.

MOTHS AND BUTTERFLIES (LEPIDOPTERA)

Sugar-Beet Webworm (*Loxostege sticticalis* Linn.).—The out-

standing entomological feature of the year was an unprecedented outbreak of the sugar-beet webworm. During the first three weeks in August millions of webworms appeared in the northern and central counties of the State. Beets, beans, corn, and garden crops were all seriously damaged. Not only were crops injured but houses were infested and wells were contaminated by the millions of crawling worms. Fortunately, grain crops were not molested. Russian thistle and pigweed are favorite food plants of this insect and much of the damage done in gardens was due to the presence of weedy areas which had attracted the moths for egg-laying and in which millions of webworms were hatched out.

White-Lined Morning Sphinx (*Deilephila lineata* Fab.).—The large green larvae of this beautiful moth were reported as very abundant near Columbus. Weeds were mainly fed upon and no damage to crops was reported.

Imported Cabbage Worm (*Pontia rapae* Linn.).—As usual, the cabbage worm was highly destructive throughout the State and numerous letters were received from owners of war gardens who were anxious to learn the best method of getting rid of this pest. Like the potato beetle, this is one of the insects that has to be fought every year.

Cutworms (*Noctuidae*).—Although no wide-spread outbreak of army cutworms occurred, yet cutworms were more abundant throughout the State as a whole than for several years. War gardens in many communities suffered severe setbacks, corn, peas, and beans having to be replanted several times in order to get a stand. In several counties, grain crops and alfalfa were badly injured.

Webbing Clothes Moth (*Tineola biselliella* Hummel).—Clothes moths were unusually abundant during the summer months. In some instances, larvae were found in great abundance and doing damage in November.

Mourning Cloak Butterfly (*Euvanessa antiopa* L.).—The larvae of this butterfly, commonly known as the spiny elm caterpillar, have been reported many times as working on elm and willow foliage and during the past season have worked on cottonwood foliage as well.

Tortoise-Shell Butterfly (*Eugonia californica* Bois).—Residents in the western end of the State reported great swarms of these butterflies, particularly in Sanders County. Farmers feared that

their presence in such large numbers forecast a brood of injurious caterpillars but such was not the case. This species is not known to be injurious to plants of value.

Luna Moth (*Tropaea luna* Linn.).—The County Agent of Richland County reported that the larvae of this beautiful moth stripped the foliage from the box-elder trees.

FLIES (DIPTERA)

Wheat Stem Maggots.—Early in the spring numerous complaints were received from grain growers in southern and eastern Montana, stating that a small, white maggot was destroying both winter and spring wheat by boring through the central stem. An investigation showed that two species of maggots, hitherto unknown in Montana, were doing the damage.

Onion Maggot (*Phorbia ceparum* Meade).—Like the cabbage maggot, this insect is becoming more abundant and destructive each year.

Cabbage Maggot (*Phorbia brassicae* Boche).—Each year the cabbage maggot becomes more troublesome to gardeners, especially in the northern parts of the State. Turnips, rutabagas and radishes are also attacked.

Nose Fly (*Gastrophilus haemorrhoidalis* Linn.).—The nose fly has now spread throughout the State and is a constant source of irritation to horses during the hot summer months.

Currant Fruit Fly (*Epochra canadensis* Loew.).—Owing to the total failure of the currant crop in many parts of the State, fewer inquiries than usual were received concerning this pest of the currant and gooseberry.

Mosquitoes (*Culicidae*).—Several requests for aid in mosquito control campaigns were received but, because of lack of funds and the pressure of other work, no help could be given.

THE BEETLES (COLEOPTERA)

Pea Weevil (*Bruchus pisi* Linn.).—It is now definitely established that the pea weevil can breed rapidly in Montana. Weevil-infested peas planted by a farmer in the Yellowstone Valley yielded a badly infested crop last year and again this year. It is to be regretted that this enemy of the seed pea industry has now become established within the State.

Colorado Potato Beetle (*Leptinotarsa decemlineata* Say).—Potato beetles were more plentiful than for several years. Their unusual abundance, coupled with the scarcity of Paris green, caused considerable loss in some districts. Calcium arsenate and zinc arsenite were used with good success in place of Paris green.

Flea Beetles (*Epitrix* sp.).—Flea beetles were very abundant, causing considerable anxiety to owners of war gardens during the spring months. In most cases the injury was outgrown before the growing season was over.

Nuttall's Blister Beetle (*Cantharis nuttalli* Say).—This brightly colored beetle was reported as cutting the blossoms and buds of beans. Some damage was also done to alfalfa.

Wireworms (*Elateridae*).—Wireworms were more abundant than usual, attacking many different kinds of crops. Wireworm injury of an uncommon sort was reported from Three Forks where sprouting peas were riddled so badly that a very poor stand was secured.

Sunflower Beetle (*Chrysomela exclamationis* Fab.).—For the past two seasons, both wild and cultivated sunflowers have been attacked by this beetle.

BEES AND WASPS (HYMENOPTERA)

Currant Sawfly (*Gymnonychus appendiculatus* Hartig).—The larvae of this sawfly were reported as defoliating currants and gooseberries.

Leaf-Cutter Bees (*Megachile* sp.).—Each year numerous letters are received concerning this interesting although destructive bee. In the shelter-belt plantings in eastern Montana it is a very serious pest, as it nearly defoliates the ash tree, which otherwise is one of the most desirable trees that can be planted in the plains area.

REVIEW OF THE YEAR 1918

Each year has its outstanding entomological incidents or features. In addition to certain insects which are regularly present and destructive, there are those that come unexpectedly, and it is often impossible for us to determine in advance what the principal interests are to be. The season of 1918, on the whole, was an active one, there being many pests that were brought to our attention and a few that were widespread and very injurious.

GRASSHOPPERS IN 1918

In view of the extensive damage caused by grasshoppers in 1917 we were on the alert in the spring of 1918, looking for any outbreaks which might occur in any part of the State. Our attention was especially directed toward those localities which had suffered most heavily in the previous year. As mentioned on page 207 of my last report, it was feared the species of grasshopper which had appeared in great numbers was none other than the Rocky Mountain migratory locust which some fifty years ago had wrought such serious and extensive damage over a large part of the United States and that we might reasonably expect a repetition of the devastation wrought in the earlier years. On the whole, grasshopper damages were less severe than in 1917, but there were reports from numerous widely separated parts of the State, most of which were looked into by representatives from this office. The particular long-winged species resembling, if not identical with, the Rocky Mountain migratory locust which had prevailed in 1917 appeared again in some localities but, for the most part, the damage in 1918 was caused by miscellaneous resident species which are always present in greater or less numbers. Among these were the Yellow-Winged Locust or the Warrior Locust (*Camnula pellucida* Scud.), the Two-Striped Locust (*Melanoplus bivittatus* Say), the Big-Headed Grasshopper (*Aulocara elliotti* Thomas), and various others.

The species resembling the Rocky Mountain locust was abundant and injurious in a region extending through the southern portion of Broadwater and the eastern portion of Gallatin counties. In this region, which also had been visited by this insect the previous season, some thousands of acres of wheat were seriously damaged. Some fields were completely eaten off. The farmers were energetic in their efforts to control the outbreak and poison bran mash and 'hopper catching machines were used. This locality was visited by Mr. J. R. Parker and myself in September and we found that the insects had very largely disappeared without laying eggs. While earlier in the year the long-winged grasshopper had prevailed throughout this region, at the time of this visit the grasshoppers that were present were of other species.

Parasitic flies (*Sarcophaga* spp.) were present in great profusion and we believe that in this locality, as in western Montana in 1917, these parasites were very effective in the prevention of what

easily might have become a veritable plague of grasshoppers. As may be inferred from the above, little damage from grasshoppers occurred this season in the region extending through parts of Flathead, Missoula, and Sanders counties, where in 1917 serious losses were occasioned.

In the upper part of the Bitter Root Valley, in Ravalli County, there was an outbreak of considerable importance which when investigated was found to be due to the warrior grasshopper mainly, though some other species were sparingly represented. Other counties where grasshoppers were reported are Rosebud, Madison, Fergus, Sweetgrass, Meagher, and Cascade.

The use of poison bran mash was recommended and it was much used throughout the State; the catching machine, designed to catch the living grasshoppers, also was generally used.

A circular entitled "Grasshopper Control in Montana" was issued early in the present season. This circular (No. 76) discusses the subject of grasshopper control, gives the results of our experience in the previous year, and contains seventeen new illustrations.

CUTWORMS IN 1918

The office received many complaints of cutworm troubles, coming mainly in May and June. It was on the whole one of the worst cutworm years we have had. Specimens sent in were in many instances reared to the adult or moth condition and were found to belong mainly to the species *Euxoa ochrogaster* Guen. The species was present and quite injurious for upwards of two months, and in this respect differed strikingly from *Chorizagrotis auxiliaris* Grote, the army cutworm which, when it comes, appears in excessive numbers in May and then suddenly disappears. This species, known as the red-backed cutworm, has never been known to become exceedingly abundant in Montana and take on the army habit. A peculiarity is that it keeps under the ground more than the other species and is more apt to cut plants off beneath the surface.

This insect was particularly troublesome in gardens, where practically all kinds of cultivated plants were eaten. Many gardens were injured for the season by cutworms destroying the stands of such crops as carrots, spinach, beets, and radishes, which were sown in the drill row, and cabbages, cucumbers, and others planted or set in hills. The attacks were by no means confined to gardens,

however, for many fields of spring wheat and fall wheat, as well as of other grains, were damaged.

This is one of the species about which we need more information and research is now being conducted under the Adams fund.

THE COLORADO POTATO BEETLE

In view of the urgent feeling of necessity for producing as much food material as possible this season, the unusual abundance of the common potato beetle was especially noticeable. Early in the season before the new plants had broken through the ground the adult beetles, which had passd the winter in hibernation in the soil, were much in evidence and when the young plants appeared they were set upon at once. Many people in the State resorted to hand picking and in view of the desirability of prompt action and the scarcity of insecticides it was probably the best thing that could be done on small patches. Large fields are not generally attacked by enough of the adults in the early spring to do serious harm to the plants. This is explained by the fact that the beetles congregate from the surrounding territory and the larger the field the larger the number of plants for them to spread out upon. When the larvae or slugs appeared later in the season it became evident that we were confronted by an unusual abundance of these insects. Steps had already been taken to aid the farmers in having available a supply of poison and attention was called to the fact through the press that arsenite of zinc, which was cheaper and entirely satisfactory, was available in place of Paris green and arsenate of lead, both of which contain chemicals of much importance in the war industries.

A LITTLE KNOWN STEM MAGGOT OF WHEAT

One of the most interesting features of the season's work was the occurrence in May of a maggot in the stems of young winter wheat plants at a number of widely separated points in Montana. Specimens were sent in with inquiries and maggots were reared in the insectary with the result that a very unusual fly was secured. The specimens were examined by Dr. J. M. Aldrich, a specialist in the Diptera, who found them to be *Hylemyia cerealis* (Gillette), an insect which Professor Gillette reared from wheat in Colorado and about which he wrote very briefly in Bulletin 94 of the Colorado Experiment Station, December, 1904, pp. 14, 15.

It is too early to state how serious this pest may become but it is certainly serious, and rather extensive damage was done this year. Further studies on this insect are to be made next year if it is present.

THE SUGAR-BEET WEBWORM

An outbreak of small striped caterpillars appeared about the 10th of August throughout the major part of the State east of the continental divide. Letters and telegrams came in rapidly from farmers and county agents. While no great amount of damage, excepting in gardens, was finally done, the fact that the caterpillars were generally scattered throughout grain fields, where they were feeding on weeds, caused much uneasiness among the farmers who feared that when the weeds were gone the grain would be attacked. The insects continued in abundance for about ten days. The species concerned was found to be one which has been known as the sugar-beet webworm (*Loxostege sticticalis* L.). This insect is a very general feeder. During this season it was reported on corn, cabbage, beets, alfalfa, gooseberry, and currant bushes, among cultivated plants, but weeds were particularly mentioned and the Russian thistle standing in grain crops was often spoken of. In view of the shortage of hay and other feeds for stock in some parts of the State some farmers were planning to cut Russian thistle as feed but were prevented by the insects which ate down this weed completely. Pigweed (*Chenopodium*), is a favorite also, and spinach, onions, celery, and tomatoes have been mentioned by other writers as being food plants.

These caterpillars were present in incredible numbers. They moved about to some extent and devoured the vegetation as they advanced. It was reported repeatedly that they were "eating everything green." It was also reported to us that they had stopped railway trains, which is entirely possible and would be due to the crushing of their bodies on the rails, thereby making such a slippery track that the locomotives could not pull the trains. Circular 42 of this station (June, 1914), entitled "The Sugar-beet Webworm" by J. R. Parker was sent out very generally and the remedies proposed were effective.

It is not necessarily true that this insect will return next season. Parasites are very effective in its control and judging by past

experience in Montana it is not expected that the webworm will be more than usually abundant in 1919.

THE FALSE CHINCH BUG

Again and again we have had reports of the supposed occurrence of the chinch bug (*Blissus leucopterus* Say) in various parts of Montana but in nearly every case the insect concerned has been the false chinch bug (*Nysius ericae* Schill). This very common insect, a drawing of which appears on the cover page of this report, in size and habits resembles somewhat the very destructive true chinch bug which we believe does not occur in Montana except scatteringly in a few counties in north central Montana where it has been present several years to our knowledge but without being very injurious.

The false chinch bug was injurious mainly to garden plants which were attacked by great numbers of the insects clustering on the terminal growth and sucking out the juices. Some measure of alarm was felt by farmers as it was feared that extensive damage to grain and corn might result from the excessive numbers of the false chinch bug. No damage was done to field crops, however, so far as we can judge from the reports that reached us.

According to Milliken, ("Nysius ericae, The False Chinch Bug," in Journal of Agricultural Research, Vol. XIII, No. 11, p. 571, 1918) there are in Kansas six or seven generations of this insect per year. This writer found that about a month is required to complete one life cycle at a temperature of 79.78 degrees Fahrenheit. We cannot state definitely how many generations there are in Montana but it is clear there are several. These insects multiply with rapidity and it is not surprising that such great numbers appear. We have often found them congregated in large numbers on and under weeds during hot days. The carpet weed, or purslane, is a favorite food and shelter and often touching such a weed with the foot will cause hundreds of these small insects to scurry away in all directions. Mr. J. R. Parker, while traveling in Flathead County on August 5, 1910, found various plants, including potatoes, carrots, raspberry bushes, turnips, and strawberry plants being damaged by great numbers of these insects which clustered on the growing terminals, causing them to wilt. Potatoes were particularly in danger as the adults had settled upon them in great numbers. Beets are

known to be a favorite food plant and in view of its great power of multiplying it would not be surprising if the false chinch bug were to become a serious pest of the sugar beet in Montana.

The control methods are much the same as for the true chinch bug, and were brought to the attention of those who inquired.

ALFALFA WEEVIL QUARANTINE

An effort was made last December (1917) by growers of salt grass hay in Utah to induce us to suspend or modify our quarantine of hays in force because of the alfalfa weevil, and allow salt grass hay to be shipped in for use as packing in place of excelsior. It became evident in the course of the correspondence that we did not possess sufficient information to deal intelligently with the situation and that what we needed was first-hand facts. Accordingly a conference of representatives from the various interested western States was called by Governor Bamberger of Utah. Representatives were present from Colorado, Idaho, California, and Montana. We met at Salt Lake on June 20th and 21st and were welcomed by Governor Bamberger in the Senate Chamber of the Utah State Capitol, following which a chairman and secretary were elected. In the afternoon of the first day we were taken on a tour of inspection into the territory where salt grass is grown and the method of handling it was explained. It had been represented to us previously that no alfalfa was grown in the flats where this salt grass abounds, but in the course of the afternoon's trip it was found that on the drier spots alfalfa was being grown and this in close proximity to where salt grass was cut and stacked. Alfalfa weevils were here in abundance in and near the alfalfa fields. It was very evident that the weevils could easily make their way to the neighborhood of the stacks where, as the salt grass is baled like ordinary hay, the weevils could easily be included in the bales. The delegates agreed, therefore, that it was not safe to allow the importation of this material and it appearaed for a time that nothing could be done to relieve the situation for Utah. It is quite possible that much of the salt grass hay is cut in localities remote from where alfalfa is grown, and conceivably from such localities the hay could be packed with safety to our interests, but there was no way to distinguish in a regulation between safe and dangerous localities.

During the discussion at the Senate Chamber the next day it

was learned from Mr. Reeves of the Bureau of Entomology that the alfalfa weevil becomes inactive when the temperature falls below 60 degrees F. A considerable amount of research along this line had been done by the Bureau. This served as a suggestion to the conference that the salt grass might be raked, stacked, baled, and shipped with safety between October 1st and April 1st, provided this was done only on days when the temperature fell below 60 degrees. After extended deliberations the following resolution was passed:

Resolved, That the material known locally in Utah as "Salt Grass Packing" be admitted into the states now maintaining a quarantine against alfalfa, straw, and other hay from Utah because of the presence of the alfalfa weevil, provided that such material be cut only between the dates of October 1 and April 1, and that the raking, shocking, stacking, baling and shipping of this material, as a commercial product, be allowed only after the maximum daily temperature of the season has fallen below 60 degrees F.

Provided, further, that a certificate from the Crop Pest Inspector of the State of Utah, showing that these requirements have been met, accompany each shipment.

Provided, further, that no salt grass packing shall be held over in the field from one season to another.

Be it further resolved, That the use of such salt grass hay as a packing material in shipments of fruits, crockery, and other materials be permitted. provided it has been cut and removed from the field between October 1 and April 1, as above specified, and stored in warehouses remote from alfalfa fields, alfalfa hay, or other suspected materials.

Upon returning to Montana Mr. A. L. Strausz, State horticulturist, and the writer recommended that our quarantine be modified to agree with the resolution and to cover new territory known to be infested with the weevils and also to cover a change in the requirements regarding emigrants' movables, as recommended by the conference. The quarantine as now in force, therefore, reads as follows:

QUARANTINE NO. 4

WHEREAS, It has become known to me that an injurious insect, popularly called the alfalfa weevil, and scientifically known as "**Phytonomus posticus,**" exists and is dangerously injurious to alfalfa in the State of Utah, and in certain counties in the State of Idaho, to-wit: Bingham, Cassia, Bear Lake, Oneida, Bannock, Franklin, Power and Payette; and in certain counties in the State of Wyoming, to-wit: Unida and Lincoln; and in a certain county in the State of Colorado, to-wit: Delta:

NOW, THEREFORE, I, S. V. Stewart, Governor of the State of Montana, under and by virtue of the authority conferred upon me by Chapter 61 of the Session Laws of the Thirteenth Legislative Assembly, do hereby declare and proclaim a quarantine against the said State of Utah, and said counties of Bingham, Cassia, Bear Lake, Oneida, Bannock, Franklin, Power and Payette in the State of Idaho; and the counties of Unida and Lincoln in the State of Wyoming; and the county of Delta in the State of Colorado, and forbid the importation into Montana of the following agricultural products and other articles, excepting under conditions and regulations as specified:

1. Alfalfa hay and other hays of all kinds and cereal straws, excepting the material known locally in Utah as salt grass packing hay, which shall be admitted into Montana provided that such material be cut only between the dates of October 1 and April 1, and that the raking, shocking, stacking, baling or shipping of this material as a commercial product be allowed only after the maximum daily temperature of the season has fallen below sixty degrees Fahrenheit.

   Provided further that a certificate be required from the Crop Pest Inspector of the State of Utah showing that these requirements have been met, which certificate shall accompany each shipment. Provided further that no salt grass packing hay shall be held over in the field from one season to another. The use of salt grass hay as a packing material in shipments of fruit, crockery and other materials is permitted. provided said salt grass has been cut and removed from the field between October 1 and April 1 as above specified and stored in warehouses removed from alfalfa fields, alfalfa hay or other suspected materials.

2. Fresh fruits and vegetables, exclusive of potatoes, excepting under the following regulations:

   a. Shipments for Montana to be made only from points designated by the recognized State Pest Inspection Officers of the State shipping into Montana, said officers to notify the State Horticulturist of the State of Montana by registered mail or by telegraph of the designation of all shipping points in the aforesaid State of Utah, or counties of Bingham, Cassia, Bear Lake, Oneida, Bannock, Franklin, Power and Payette in Idaho; or counties of Unida and Lincoln in Wyoming; and the county of Delta in Colorado; said notification to be sent and its receipt to be acknowledged before any shipments are made to the State of Montana from said designated points.

   b. Shipments to be repacked from orchard or field boxes into new, clean boxes or other fresh containers.

   c. All wagons or other conveyances used in hauling to the place where repacking is conducted to be kept free from alfalfa hay or other hays, straw, and all other means of contamination.

   d. All packing houses to be at all times free of alfalfa hay, other hays, straw, and other means of contamination.

   e. Each lot shipment shall bear an official certificate of the State from which the shipment originates stating that it has been inspected and passed in compliance with these regulations and stating where it was repacked and inspected.

3. Potatoes unless accompanied by an official certificate signed by the recognized State Pest Inspection Officer of the State from which such shipments of potatoes originate, setting forth that the potatoes have

been passed over a screen, placed in fresh, clean sacks and packed in cars that are free of alfalfa hay or other means of contamniaton.

4. All nursery stock, unless accompanied by special certificate setting forth that such nursery stock has been fumigated for the alfalfa weevil in an airtight enclosure subsequent to being boxed, baled or packed for shipment, with cyanide of potassium or cyanide of sodium at the rate of one ounce to each one hundred cubic feet of enclosed space.

5. That no shipment of household or emigrants' movables originating in any State or county designated as infested with the alfalfa weevil shall be brought into the State of Montana by any common carrier, person or persons, unless such shipments be accompanied by a copy of a sworn statement made in duplicate by the owner or shipper after the following forms on blanks which will be furnished to applicants by the State Horticulturist of Montana. Copy No. 1 to be mailed to the State Horticulturist, Missoula, Montana, and Copy No. 2 to be delivered to the common carrier agent, with a special certificate appended, to attach to waybill.

State of.. }
County of.. } ss.

I hereby solemnly swear that I was present during the preparation for shipment of the household or emigrants' goods which this affidavit accompanies; that the goods were delivered to the

.... at.. on
(Railroad) (Station)

....constituting (less than) a carload
(Month, day, year)

....
(If carload, write initials and car No. here)

to be shipped to..
(Name of consignee)

at.. via..
(Destination) (Give initials of other lines)

that no nursery stock, vegetables or fruit is included in the shipment and that no hay or straw (except as provided for under Part No. 1 of this Quarantine) is included for packing material, or any other purpose, except as food necessary for the livestock in transit to the Montana State line; that the shipment is made up of the following: Household goods, farm implements, tools, harness, farm wagons, automobiles, stands of bees, livestock (draw a line through items not

included) ....
(Specify)

feed for animals in transit..
(Specify kinds and amount of each)

and ....
(Specify any items not included in previous classification)

....
(Shipper or owner)

Subscribed and sworn to before me..

a Notary Public in and for the State of..

County of...................................this the...day of

....19........

....
(Notary Public)

My commission expires..., 19........
The special certificate from the owner or shipper to be appended to Copy No. 2 of the sworn statement shall be after the following form:

I hereby agree to observe explicitly the requirements of the Montana Quarantine Order with regard to hay or straw (included as stock feed for use before reaching the Montana State line); household and emigrants' goods and other materials, and hereby certify that I have mailed this day one copy of the foregoing affidavit to the State Horticulturist, Missoula, Montana.

....
(Signature)

6. All railway shipments of livestock unless shipped in cars that are free of alfalfa hay, all other hays and cereal straws, throughout all that portion of the journey that is within the State of Utah, and counties of Bingham, Cassia, Bear Lake, Oneida, Bannock, Franklin, Power and Payette in Idaho; and counties of Unida and Lincoln in Wyoming; and the county of Delta in Colorado.

All Horticultural Inspectors of the State of Montana are hereby instructed and required to refuse admission into the State of Montana of all such articles as are herein designated from the said State of Utah; and counties of Bingham, Cassia, Bear Lake, Oneida, Bannock, Franklin, Power and Payette in Idaho; and counties of Unida and Lincoln in Wyoming; and the county of Delta in Colorado, except under the conditions herein enumerated. If any such articles as are hereinbefore listed be shipped into the State of Montana in violation oi this Quarantine they must be at once destroyed or returned to the shipper at his expense.

This Quarantine shall not be construed to interfere with shipments of products to the Yellowstone National Park over the Oregon Short Line Railroad, and to Idaho points via Montana over the Gilmore and Pittsburg Railroad.

This Quarantine shall take effect and be in force on and after the fifteenth day of July, A. D. 1918.

It is specifically understood and intended that this Quarantine Proclamation shall revoke all previous Proclamations on this subject by me made.

(Seal) IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State to be affixed. DONE at the City of Helena, the Capital, this the sixth day of July, in the year of our Lord one thousand nine hundred eighteen.

S. V. STEWART.

By the Governor:
C. T. STEWART,
Secretary of State.

WHITE PINE BLISTER RUST QUARANTINE

An exceedingly destructive disease of pine is prevalent in some parts of the East which, if introduced into Montana, would almost certainly do great damage to our forests of pine. This disease has not yet reached Montana. It is hoped that by prohibiting the importation of pines and of currants and gooseberries, which are alternate hosts of the disease, white pine blister rust may be delayed or even entirely prevented from gaining admittance into Montana. The quarantine follows:

QUARANTINE PROCLAMATION

Whereas, The fact has been determined that a dangerously injurious disease known as the White Pine Blister Rust (**Peridermium strobi** Kleb.) exists and is prevalent in portions of the eastern part of the United States as far west as and including Minnesota; and

Whereas, There is danger of the introduction of this disease into the great white pine forests of the State of Montana through shipments of five-leaved pines and currants and gooseberry plants:

NOW, THEREFORE, I, S. V. Stewart, Governor of the State of Montana, under and by virtue of the authority conferred upon me by Chapter 61 of the Session Laws of the Thirteenth Legislative Assembly, do hereby declare and proclaim that a quarantine be and hereby is established against the importation into the State of Montana of white pine (**Pinus strobus**), stone pine (**P. cembra**), limber pine (**P. flexilis**) and any other five-leaved pines, and currants and gooseberry plants (**Ribes** and **Grossularia**) from any part of the United States

Insects of Tree Fruits
Insects of Shade Trees and Ornamentals
Parasites on Domestic Animals
Insects Affecting the Health of Man and Animals
Household Insects
Insects in Stored Seeds and Foods.

HOW COUNTY AGENTS SHOULD HANDLE INSECT PROBLEMS

If the insect is recognized beyond a doubt, recommend the standard method of control which has been worked out for Montana conditions and is given in this book.

If the insect is not readily recognized, secure specimens and send them to the Department of Entomology at the Agricultural College. We will immediately determine them and advise control methods. Specimens to be sent through the mail should be enclosed in a tin box, together with a quantity of their food plant. In most cases no dirt should be put into the box, nor it is necessary to punch holes in the box. Never send insects in letters.

In case any insect becomes unusually abundant or is doing wide-spread injury, notify the Department of Entomology at once. In most cases we will be able to send a man to demonstrate control methods and to aid in organizing a control campaign.

ORGANIZATION

Mr. H. L. Seamans, who has held the position of assistant State entomologist, resigned to take a position as field assistant in the Bureau of Entomology on May 30th, 1917, and Mr. A. L. Strand, a graduate in entomology from Montana State College, became assistant on June 1st, 1917.

Mr. Strand went into military service in June, 1918, but his position is held for him. This position has been unoccupied since his departure. Because of the pressure on our fund, arrangements were made with the Bureau of Entomology and Mr. Strand temporarily vacated his position as assistant State entomologist in 1918 and accepted an appointment as field assistant with headquarters at Bozeman. In this position he continued to do work that was very similar to what he had done as assistant State entomologist. This arrangement continued until Mr. Strand went into the military service.

Upon the departure of both Mr. Seamans and Mr. Strand, to

binder. The book is given the title of "Standard Control Methods, Insect Pests of Montana." Following are the introductory paragraphs of the book:

STANDARD CONTROL METHODS FOR THE MORE IMPORTANT INSECT PESTS OF MONTANA

The purpose of this loose-leaf notebook is to facilitate the work of the county agents in the State of Montana and to bring about a reasonable degree of uniformity in the recommendations for the control of insect pests made in the several counties. It would be too much to expect the county agents to be especially informed in all the branches of technical agriculture and this is particularly true with such subjects as entomology, plant pathology, veterinary science, etc. This book contains the experience of the entomologists of the Department of Entomology, accumulated through a considerable number of years, and the information contained is in harmony with the most recent publications. It is our purpose to revise it from time to time, sending out new sheets and recalling old ones, as progress in entomology is made and the changes become desirable.

It is intended that this book shall contain the State standard methods and a greater degree of uniformity is therefore expected in the recommendations which we make and a greater degree of accuracy, also, in the information which we give to farmers regarding the habits of such insects. The need of greater uniformity will be apparent when it is realized that in the past county agents, who have been trained in widely separated states, have been called upon to make recommendations for the control of insects with which they are not very familiar and species which in many instances have been recently the subject of research in one state or another.

The various sheets are grouped by subjects and the various subjects are separated by tab-labeled sheets which will facilitate the filing of new sheets and the every-day use of the book. The headings of the book are as follows:

Insects of Grain and Corn
Insects of Field and Root Crops
Insects of Grasses and Forage Crops.
Insects of Garden Crops
Insects of Small Fruits

QUARANTINE PROCLAMATION

WHEREAS, the fact has been determined that a dangerously injurious plant disease known as Wheat Rust is disseminated and carried by means of Barberry bushes (**Berberis vulgaris**), both of the green and purple form; and

WHEREAS, there is danger of the introduction of this disease into the great wheat fields of Montana through shipments of said Barberry bushes and a further dissemination of said wheat rust through the agency of Barberry bushes;

NOW, THEREFORE, I, S. V. Stewart, Governor of the State of Montana, under and by virtue of the authority conferred upon me by Chapter 61 of the Session Laws of the Thirteenth Legislative Assembly, do hereby declare and proclaim that a quarantine be and hereby is established against the importation into the State of Montana of Barberry bushes (**Berberis vulgaris**) and plants from any point without the said State of Montana.

All quarantine guardians and deputy State horticultural inspectors are hereby instructed and required to refuse admission into Montana of any shipments of Barberry bushes (**Berberis vulgaris**) or plants. It shall be the duty of the deputy horticultural inspectors, or other quarantine guardians, to deport immediately such shipments or destroy them by burning. All expenses incurred in deporting or destroying such shipments shall be paid by the consignor.

Any person who sells or offers for sale, in the State of Montana, Barberry bushes (**Berberis vulgaris**) or plants contrary to this quarantine order shall be liable to prosecution under the laws of the State of Montana.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the Great Seal of the State to be affixed.

DONE at the City of Helena, the Capital, this the twenty-fourth day of April, in the year of our Lord one thousand nine hundred eighteen.

(Signed): S. V. STEWART.

By the Governor:
C. T. STEWART,
Secretary of State.

UNIFORM CONTROL METHODS FOR COUNTY AGENTS

To meet the conditions in the counties, to give thorough and up-to-date information in regard to insect pests, as well as to bring about uniformity in instructions given out by the various county agents, this office during the past year has entered upon a project for furnishing to all county agents mimeographed sheets of instructions concerning our more important pests. These have been furnished to all of the county agents' offices, bound in a good loose-leaf

east of and including the States of Minnesota, Iowa, Missouri, Arkansas and Louisiana.

All quarantine guardians and deputy State horticultural inspectors are hereby instructed and required to refuse admission into Montana of any shipments of any of the five-leaved pines above mentioned, and currants and gooseberry plants. It shall be the duty of the deputy horticultural inspectors, or other quarantine guardians, to deport immediately such shipments or destroy them by burning. All expenses incurred in deporting or destroying such shipments shall be paid by the consignor.

Any person who sells or offers for sale within the State of Montana pine seedlings, currants and gooseberry plants from the above quarantined area in violation of this quarantine order shall be liable to prosecution under the State laws of Montana.

It is specifically understood and intended that this quarantine proclamation shall revoke all previous proclamations on this subject by me made.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the Great Seal of the State to be affixed.

(Seal) DONE at the City of Helena, the Capital, this the third day of July, in the year of our Lord one thousand nine hundred seventeen.

(Signed) S. V. STEWART.

By the Governor:
C. T. Stewart,
Secretary of State.

BARBERRY QUARANTINE

For many years it has been known that the common barberry bush serves as an alternate host for stem rust of wheat, probably the most destructive of all plant diseases. A law passed in Denmark in 1903, prohibiting the growing of barberry bushes, has had such remarkable results in controlling rust in the grain fields of that country that plant pathologists in the United States have been making extensive studies to determine whether similar legislation would not solve the wheat rust problem in the Great Plains section of this country. As a result of their findings there was launched early in 1918 a campaign for barberry eradication in our great wheat-growing States. As a preliminary to this campaign of eradication, a quarantine prohibiting the importation of barberry bushes into Montana was issued, which reads as follows:

enable us to meet a difficult situation, Mr. J. R. Parker, assistant entomologist in the Experiment Station, usually occupied with research work, was temporarily removed from his regular duties and placed in charge of the State work for the control of insects and also of rodents. This arrangement was continued during the critical period when insect pests were most injurious.

COOPERATION WITH BUREAU OF ENTOMOLOGY, UNITED STATES DEPARTMENT OF AGRICULTURE

By act of Congress, under provision of the Food Production Act to stimulate agricultural production, the Bureau of Entomology secured funds which enabled it to place in the field a number of extension entomologists. This work was carried on in cooperation with the agricultural colleges and experiment stations and under definite project agreements. Montana was fortunate in securing the services of two representatives of the Bureau to demonstrate the control of insects affecting cereal and forage crops. These men were placed under the direction of the State Entomologist and were of great assistance in the campaign against the wheat stem maggot and in demonstrating grasshopper control. A representative of the Bureau of Entomology also spent several months in Montana demonstrating the most approved methods of beekeeping.

This cooperation with the Bureau of Entomology was a very satisfactory one for Montana, as we were enabled to do much more than our limited funds would otherwise have allowed. In Montana at least there can be no doubt that the purpose of the Food Production Act was accomplished in that thousands of dollars' worth of agricultural products were saved from destruction by insect pests.

NEEDS AND PLANS FOR THE COMING TWO YEARS

No important changes or enlargements in the scope of the work of the State entomologist's office are contemplated for the coming two years. Our work under this fund is marked out for us by the developments of each season. No year passes without some one or several pests becoming destructive and it is necessary to have an assistant in the field and to pay his traveling expenses. I[illegible] also necessary to conduct minor investigations at the laborat[illegible] Bozeman and to verify and supplement these studies by obs[illegible] in the fields where the insects are, wherever in the State t[illegible]

The sum of money which this office uses is surpr[illegible]

compared with the amount of saving to the agricultural interests of the State that is effected. During the past two years we have had several very important pest outbreaks. In 1917 there was the most extensive and destructive grasshopper outbreak that has been known in the State for upwards of twenty-five years. We had serious cutworm troubles in both 1917 and 1918 and in 1918 we had webworms by the millions in many counties. In 1918 we had very extensive troubles from the false chinch bug. In both of these years we have had many pests of lesser importance here and there throughout the State. The value of the crops saved by the activities of the State entomologist's office during these outbreaks was many times greater than the total appropriations received.

Our expenses, per year, for the coming biennium are estimated to be as follows:

Salary of asssistant	$1,500
Traveling expenses	800
Labor	500
Supplies and laboratory expenses	700
Total	$3,500

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AGRICULTURAL EXPERIMENT STATION

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Fifth Annual Report of the Montana Grain Inspection Laboratory

Testing seed for percentage of purity and percentage of germination at the Montana Grain Inspection Laboratory.

BY

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Fifth Annual Report of the Montana Grain Inspection Laboratory

This bulletin briefly presents a report of the activities of the Montana Grain Inspection Laboratory for the year ending October 1, 1918. Two types of work were carried on during the year. These were the grading and dockage tests of wheat samples and the determination of germination and purity of samples sent in for test.

The grading work here reported was carried on during the year closing July 1, 1918. This was the first year of the grading activity, as the provision for the work was made by the State legislature of 1917. In all, 635 samples were received and tested fully for grade, dockage, moisture, and so forth.

In the seed-testing department, 12,604 samples of various kinds of seeds were tested for germination and purity.

Grading Equipment and Work

The legislature of 1917 authorized the establishment of a grading department of the grain inspection laboratory and provided funds for its equipment and maintenance. This laboratory is for the purpose of furnishing information on the true grade and proper dockage of grain samples that may be sent in.

Farmers and dealers are urged to make full use of the laboratory. The tests will be made and reports returned without expense to the sender.

Samples should be not less than two quarts in size, and should be delivered in person or transmitted by prepaid express or by parcel post. They should be addressed to the State Grain Inspection Laboratory, Bozeman, Montana, and in every case the package should contain a card or slip of paper showing the name and address of the party to whom the report is to be returned.

In case of dispute as to grade or dockage, a representative sample should be taken from the lot of grain in the presence of repre-

sentatives of both parties and should be sent to the laboratory. This should be accompanied by an agreement in the following form signed by both parties:

We agree that the accompanying sample taken from a certain lot or parcel of grain described and identified as follows:... is a representative sample of such lot or parcel involved in an appeal taken to the Montana Grain Inspection Laboratory. This was taken by..................................... .... at...P. O., in accordance with the rules and regulations of the Montana Grain Inspection Laboratory (Circular No. 68).

Place...

Date..

...
Complainant

...
Respondent

LABORATORY EQUIPMENT

The Montana Grain Inspection Laboratory is equipped with modern apparatus for establishing the true grade and determining the proper dockage on all wheat samples sent in. Standard methods are employed in making these determinations and in this way personal errors and variations in results are reduced to a minimum.

THE SAMPLING OF GRAIN

In order to be able to make a true grade determination it is essential to obtain a representative sample. In case of bin, wagon, or car-load lots, this can be done by means of probes (fig. 1). At least five probings should be taken and as many more as the sampler may see fit. The grain taken from the different portions of a lot should be thoroughly mixed so that this mixture constitutes a representative sample of the entire lot. A small portion of this is placed in an air-tight container and kept for a moisture test.

In order to make a very careful analysis, the sample lot of grain must be reduced in weight. Figure 2 illustrates a device which divides the sample into smaller portions and at the same time maintains the proper proportion for the various factors of the original sample.

SCALES

Figure 3 shows two sets of scales. The one on the left is graduated to 500 grams and is used to weigh a given amount of grain which has been sampled down and on which the percentage of dockage is to be determined. In order to fill the one-quart tester, two drafts are taken and the dockage is then weighed back.

The scale to the right is sensitive to 0.005 of a gram and is used to determine the percentage of wheat of other classes, percentage of damaged kernels, and percentage of materials other than dockage.

THE MOISTURE TESTER

Figure 4 represents two official standard moisture testers as described in Circular No. 72 of the Bureau of Plant Industry, United States Department of Agriculture. This apparatus is devised to extract the moisture from the grain. The moisture content of all important samples should be determined. This is done in duplicate and the average of the two tests is taken. They should check up to one-tenth of one per cent. As the moisture content is a very important factor in determining the number of the grade and very few of our mills and elevators are equipped with this special apparatus, samples should be sent to this laboratory for this determination.

SEPARATING DOCKAGE FROM WHEAT

The following cleaning devices are used in determining the quantity of dockage in wheat.

Wild-oat kicker.—On account of the short, jerky motion of this machine (fig. 5), it has been designated as the "wild-oat kicker." It is used in removing barley, oats, wild oats, pieces of straw, weed stems, and other coarse materials from the wheat.

FIG. 1.
Grain trier (probe)

Hand sieves.—The set shown in figure 6 consists of bottom pan, buckwheat sieve, fine seed sieve, fine chess sieve, coarse chess sieve, and scalper sieve. It is very essential that the dimensions of the perforations be perfect as a slight variation will materially influence the percentage of dockage

FIG. 2. Sampling device for dividing a sample into smaller portions and still maintaining the proper proportion for the various factors of the original sample.

obtained. These sieves are used in connection with the wild-oat kicker, those used depending largely upon the kind of material found in the wheat. When properly used a practical determination of dockage should be obtained.

TEST WEIGHT PER BUSHEL

This determination is made on dockage-free wheat and is one of the main factors in determining the grade of grain. A sufficient quantity of the original sample should be freed from dockage to

FIG. 3. Balances for determining the percentage of dockage and the various factors which may affect the grade.

permit the test weight to be made with a one-quart kettle. One thousand grams of wheat containing the dockage, under average conditions, will give enough dockage-free wheat for this determination. As it is a simple matter to vary the test weight on a given sample of grain from one to two pounds per bushel by the manner in which the tester is filled, the following rules are observed:

1—Fill the test kettle from a hopper,—

a. Having an opening 1¼ inches in diameter at the base.

b. Firmly supported 2 inches above the test kettle.

2—Have the test kettle rest on a firm base.

3—Fill the kettle every time with the same amount of overflow.

4—Strike the excess grain from the top of the overflowing kettle in a uniform manner with three zig-zag motions with the sides of the special stroker held vertically, avoiding, meanwhile, any jarring of the contents.

5—Make the weighings on a beam accurately graduated to read in fractions of a pound.

DOCKAGE

The determination of the proper amount of dockage is one of the most important factors in grading. Unless this is done correctly

FIG. 4. Official moisture tester for determining the moisture content of grain.

there is apt to be an error in the weight per bushel, percentage of damaged kernels, or percentage of inseparable impurities, thus altering the entire grade. Oftentimes the dockage itself has considerable commercial value. Frequently it consists of flax, wild oats, or other nutritious seeds which are valuable for feed. This material in many instances can be removed in practically a pure state with ordinary cleaning machinery such as is used in large mills and terminal elevators. This dockage commands a good price on the market. It would therefore be to the best interests of the farmers to clean their grain before selling as they receive no compensation whatever for this material but, on the contrary, donate a product of appreciable commercial value to the grain buyers. If this material were separated on the farm it could be ground and used for feed.

The average dockage for all the samples graded the past year at the Montana Inspection Laboratory was 2.78 per cent. This means that for every bushel of wheat hauled to the market, approx-

FIG. 5. Wild-oat kicker for removing barley, oats, wild oats, pieces of straw, weed stems, and other coarse matter from wheat.

imately 1.7 pounds of weed seed, chaff, sticks, or dirt was also transported. Figuring 2.78 per cent as the average dockage on 18,550,000 bushels—our 1917 wheat crop—we would have 515,690 bushels dockage. This, at a very low rate, would mean that our farmers are annually losing thousands of dollars' worth of feed, besides paying a substantial amount in freight charges.

THE GRADING WORK

The official grades for wheat as announced by the Bureau of Markets of the United States Department of Agriculture, which apply in interstate shipments, are used as the official grades in Montana. These were announced as effective July 1, 1917, for winter

TABLE I.—SHOWING RESULTS OF THE GRADING OF WHEAT AT THE MONTANA GRAIN INSPECTION LABORATORY FOR THE YEAR ENDING JULY 1, 1918.

Total number of samples graded, 635.

	Hard Red Spring 370 samples				Hard Red Winter 187 samples				Common and Red Durum 51 samples			Soft Red Winter 12 samples			Common White 10 samples			White Club 5 samples	
	Dark Northern Spring	Northern Spring	Red Spring	Hard Red Spring Mixed	Dark Hard Winter	Hard Winter	Yellow Hard Winter	Hard Red Winter Mixed	Amber Durum	Durum	Common and Red Durum Mixed	Red Winter	Red Walla	Soft Red	Hard Winter	Soft Winter	Mixed	White Club	Mixed White Club
No. of samples..	126	215	16	13	29	114	5	39	13	1	37	9	1	2	3	5	2	3	2
Grade 1 (per cent)	61.9	51.6	43.8	38.5	37.9	24.6	..	20.5	23.1	..	29.7	33.3	..	50	..	40	..	66.7	50
Grade 2 (per cent)	17.5	22.8	12.5	23.1	31.0	32.5	40	28.2	46.2	100	37.8	22.2	100	50	33.3	40	50	33.3	50
Grade 3 (per cent)	7.1	11.6	12.5	..	24.1	23.7	20	30.8	7.7	..	16.2	44.5	..		33.3	20	50	..	..
Grade 4 (per cent)	4.0	4.2	12.5	7.7	6.9	14.0	20	12.8	15.4	..	27.0	..	..		33.3	..	..	..	..
Grade 5 (per cent)	1.6	3.3	..	15.4	..	2.6	..	5.1	..	..	27.0	..	..		..	..	..	..	..
Sample grade (per cent)	7.5	6.5	18.8	15.4	..	2.6	20	..	7.7	..	10.8	..	..		..	..	..	..	..
No. of samples grading smutty	5	23	2	2	4	26	4	18	0	0	3	8	0	2	0	0	0	0	0

FIG. 6. Sieves for determining the dockage of wheat; to be used in connection with the wild-oat kicker.

wheat and August 1st of the same year for spring wheat (Service and Regulatory Announcements, Bureau of Markets, No. 22). Since the announcement and up to July 1, 1918, the laboratory has graded and determined the dockage on 635 samples. These were sent in by farmers and grain dealers from practically every portion of the State where wheat is grown. The results of determinations made on these samples are shown in Table I.

This table shows the number of samples in each class, the number of samples in each subclass, as well as the percentage of these that graded Number 1, 2, 3, 4, 5, Sample or Mixed.

In the class Hard Red Spring there were 370 samples; 215 or 58.1 per cent of these graded Northern Spring. Of this number 51.63 per cent graded No. 1.

In the class Hard Red Winter, of which there were 187 samples,

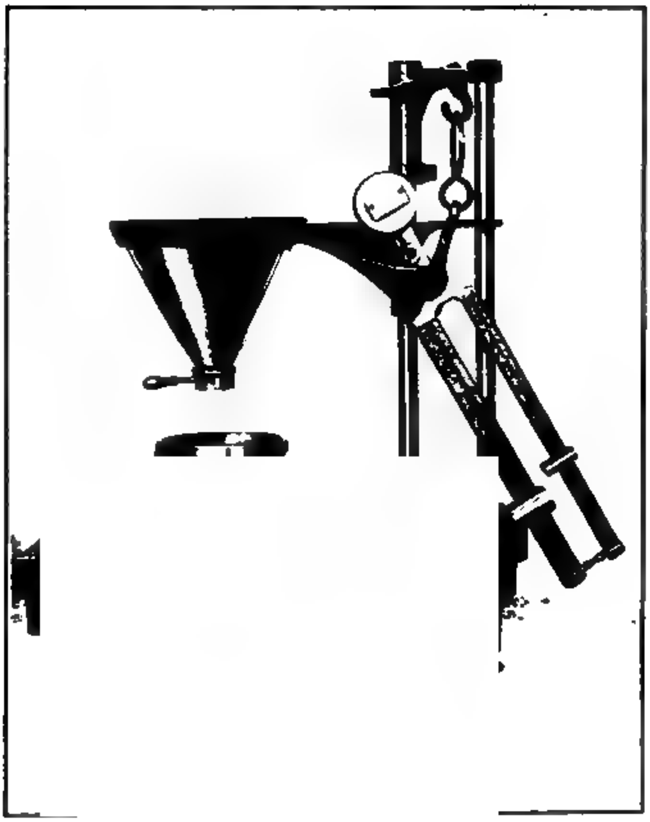

FIG. 7. Apparatus for determining the official test weight per bushel, showing the funnel for filling the test kettle in a uniform manner, the special beam, and the special stroker for striking the excess grain from the top of the test kettle.

114 were classified as Hard Winter, the majority or 32.45 per cent grading No. 2.

Of 51 Common and Red Durum samples, 37 were graded as Common and Red Durum; 37.83 per cent of these graded No. 2.

For the class Soft Red Winter the greater portion graded No. 3 Red Winter.

There were hardly enough samples of the classes Common White and White Club to draw any definite conclusions.

Smut seems to be more prevalent in the winter than in the spring wheat samples.

It was found that, in the majority of cases, the test weight per bushel was the prevailing factor in determining the grade. Next to this the percentage of damaged kernels other than heat-damaged seemed to be the deciding factor. Mixtures of wheat of other classes and mixtures of inseparable impurities followed in the order named. Owing to the fact that the 1917 growing season was especially long and comparatively free from adverse climatic conditions, very few samples were lowered in grade on account of heat-damaged kernels or excessive moisture.

Seed Report

SOURCE OF SAMPLES

Seed samples from nearly every portion of the State have been received for both germination and purity tests. The majority have been from farmers and at present nearly every county is well represented. This shows that the farmers realize the value of planting tested seed. In order to get some knowledge of the correct amount of seed to sow, it is very essential to know the percentage of germination and purity so that a uniform stand of grain may be had.

PURITY OF GRAINS AND GRASSES

A summary of the work done in determining the percentage of pure seed of grain and grass samples shows that over one-half of the tests made were of wheat. We found that these samples contained larger percentages of weed seeds and dirt than in previous years. Oats, flax, and barley all showed a slightly higher average percentage of purity this year than in former years.

A considerable number of grass seed samples were tested for purity and on the whole satisfactory averages were maintained, although many samples were below the government standards.

PURITY OF ALFALFA AND CLOVER SAMPLES

Over one-half of the legume samples sent in for test were alfalfa. These samples showed a slightly higher percentage of purity than in previous years. Both farmers and seed dealers seem to realize more and more the extreme importance of planting clean seed. Approximately over two-thirds of the samples tested were above the United States Standard.

The clover samples, although comparatively low in percentage of purity generally, show a small increase in average over that of former years.

GERMINATION OF GRAINS AND GRASSES

During the past year over 6,500 samples of grains and grasses were tested for germination. A study of these shows a very low average germination of the corn; 1,311 samples of corn were tested, averaging but 60.63 per cent. This low average was undoubtedly due to adverse weather conditions during the ripening season. Of the 1,311 samples tested, 1,023 were below the government standard. Much of the corn sent in was of a very low seeding value.

Wheat, oats, flax, and barley samples showed slightly lower averages of germination than usual, but no marked differences were apparent.

The grasses averaged rather high in germination.

GERMINATION OF ALFALFA AND CLOVERS

The germination of alfalfa seed was not so satisfactory as last year but the clovers were appreciably higher than usual. Alsike clover showed an unusually high percentage of germination. Of 36 samples tested, every one was above the United States Standard of 75 to 80 per cent. Hard seeds in both the alfalfa and clover samples averaged about 23 per cent. As a whole, Montana-grown alfalfa and clover are of good strong germinating vitality.

AVERAGE GERMINATION OF VEGETABLES AND FLOWERS

Eight hundred and thirty-two samples of vegetable seeds of all kinds were tested. No outstanding features were apparent in summarizing the average germination obtained.

Five hundred and seventy-seven samples of flower seeds were received. The average germination of all samples was 69.12 per cent. Thirty samples of herbs tested showed an average germination of 50.98 per cent.

DISTRIBUTION OF WEED SEEDS

Weed seeds continue to increase in nearly all of the different crop seeds. It is a noticeable fact that among these we find some of the most obnoxious varieties, such as dodder, wild oats, wild mustard, fanweed, and quack grass. In our grain and grass seed samples especially, we find great increases in the percentages of

wild mustard, lamb's-quarters, Russian thistle, green foxtail, pigweed, wild buckwheat, ragweed, wild sunflower, wheat grass, wild oat, false flax, cow cockle, hare's-ear mustard, yellow foxtail, and fanweed.

In the clover and alfalfa samples the same weeds seem to be prevalent with the addition of dodder, sweet clover, curled dock, plantain, gumweed, sheep sorrel, smartweed, five-finger, pepper-grass, and shepherd's purse.

Farmers should become well acquainted with these different weeds, as well as the methods of eradication, so that they will be able to guard against them.

PLANTING VALUE OF SEED

The records of the germination and purity tests completed at this laboratory point out very clearly the extreme importance of planting good seed. When purchasing seed, there are two factors to be considered in determining the planting value. Probably the most important of these is purity. Any impurities are of course detrimental to the seeding value of the lot. The second factor is germinating power or vitality. A good method for determining the planting value of the seed is to ascertain the percentage of both purity and germination, multiply the figures obtained, and divide the result by one hundred. For instance, if a sample of seed was found to have a purity test of 98 and a germination of 92, the planting value would be 90.16 per cent. This means that approximately 10 per cent of the sample purchased would be of no value as seed. Therefore 10 per cent more seed would have to be planted than in the case of 100 per cent pure viable seed. Besides this, fields often become infested with dangerous weeds, some of which are very difficult to eradicate. The farmer in this way permanently lowers the value of his land.

To determine the above planting value of any seed, it is necessary for the farmer to know the percentage of both purity and germination. The Montana Grain Inspection Laboratory is especially equipped to make these determinations. These tests will be made on all samples sent prepaid.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

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Forage Crop Experiments With Swine

BY

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Forage Crop Experiments With Swine

Two phases of the subject of forage crops for swine are treated in this bulletin. First, the question of the method of feeding is taken up. Comparisons are made of the results of feeding different amounts of barley to swine during the pasture period followed by a finishing period on full feed. Second, comparisons are made of various pasture crops commonly grown for hogs. Among the crops compared in parallel tests are red clover, rape, grain crops, and mixtures of rape and grain. Indirectly these crops are compared with alfalfa.

The Amount of Grain to Feed Swine on Pasture

Swine growers use widely different methods in feeding pigs that are on forage. The amount of grain fed varies in different cases from none up to a full feed. The relation of these practices to the profit derived from swine feeding is a question, therefore, on which more light is needed. It was with a view to obtaining data on this problem that the following series of experiments was undertaken. These experiments were carried on during the years of 1914, 1915, 1916, and 1917.

OBJECTS

The objects of the first series of experiments were to determine the effect of variations in the amounts of concentrates fed to pigs on pasture on—

1. The rate of gain.
2. The time required to reach a market finish and weight.
3. The amount of pasture required.
4. The amount of concentrates required.
5. The cost of gains and the relative profits to be derived from the various systems.

EXPERIMENT CONDUCTED IN 1914

The work of 1914 was planned and conducted by P. N. Flint and R. F. Miller, then of the Department of Animal Husbandry. This work consisted in testing the relative efficiency of 1, 2, and 3 pounds of ground barley per 100 pounds live weight fed to pigs while grazing on alfalfa. The plan of the experiment was to place the pigs on the alfalfa as soon as they were weaned and continue them throughout the pasture season with the respective amounts of grain.

PIGS USED

The pigs were divided into three equal lots shortly after weaning. At the time the experiment began they had reached an average weight of about 27 pounds. At the beginning of the experiment there were eight pigs in each lot, but, owing to their unsatisfactory condition, one pig was removed from each of lots I and II. In calculating the data, corrections were made for the amounts of feed eaten by the pigs which were removed. The pigs were weighed every ten days. A small cot or house was provided in each plot for shelter.

PASTURE

The pasture consisted of three plots of alfalfa, each containing three-fourths of an acre, which had been seeded during the spring of 1913. A fourth plot, which was part of the same tract, was used as a check to determine the yield of hay. Three cuttings of hay were removed from the fourth plot and two crops were removed from the other three plots.

RATIONS

In addition to the forage, the pigs were fed barley twice daily. Lot I was fed approximately 1 pound of ground barley daily per 100 pounds live weight; Lot II, 2 pounds daily; and Lot III, 3 pounds daily. The pigs were watered twice daily.

RESULTS OF THE 1914 EXPERIMENT

The results of this experiment are given in Table I. During the 104 days of this experiment, the following amounts of barley were consumed daily per 100 pounds live weight: by Lot I, 0.98 pound; Lot II, 1.86 pounds; and Lot III, 2.83 pounds. The gains per head daily were 0.42, 0.64, and 0.70 pound respectively for lots I, II, and III, and the respective amounts of barley consumed per

TABLE I—ALFALFA PASTURE

104 days

	Lot I	Lot II	Lot III	Check
Barley fed daily per cwt.................(lbs.)	1	2	3	
Size of plots (acres)...........................	0.75	0.75	0.75	0.75
Average number of pigs per acre.............	16	16	21	
Pasture actually used (acre)..................	0.45	0.43	0.39	
Number of pigs in lot.........................	7	7	8	0
Average barley consumed daily per cwt.* (lbs.)	0.98	1.86	2.83	
Initial weight of lot..................... "	201.00	202.00	221.00	
Average initial weight per pig.......... "	28.70	28.90	27.C0	
Final weight of lot..................... "	507.00	669.00	803.00	
Average final weight per pig........... "	72.40	95.C0	100.40	
Total gain by lot....................... "	306.00	467.00	582.00	
Average daily gain per head............ "	0.42	0.64	0.70	
Total barley consumed.................. "	†347.20	†827.90	1478.50	
Barley consumed per pound gain....... "	1.13	1.77	2.54	
Hay removed from lots................. "	‡1845.00	‡1920.00	2180.00	4555.00

*The weight used in calculating the barley consumed per 100 pounds daily was the average of all the weights taken at 10-day intervals during the experiment.

†Correction was made for feed eaten by pig which was removed from the lot.

‡No correction was made in the amount of hay removed from lots I and II to offset the forage consumed by the pigs which were removed during the course of the experiment.

pound gain were 1.13, 1.77, and 2.54 pounds. Thus we find that when the barley is increased up to 3 pounds per 100 pounds of live weight daily, the rate of gain is increased, but that the amount of barley required to put on a pound of gain is increased also. On the other hand, the pigs which were fed 3 pounds of barley daily per 100 pounds live weight consumed less alfalfa, as the amount cut for hay was greater in this case. Further, Lot III reached an average weight of 70 pounds a month earlier than did Lot I. This slower rate of gain would represent a difference of approximately twenty days in the time of reaching the 200-pound weight, provided the pigs were put on full feed at the close of the pasture season. No data are available on the length of the finishing period actually required in this case. The value of the earlier finish depends on the season during which the pigs are to be sold.

EXPERIMENT CONDUCTED IN 1915

In 1915 the experiment was planned and conducted by C. N. Arnett and R. R. Dodderidge, following much the same lines as in 1914. The same pasture plots were used as in the previous year. The principal change in the work was to finish the lots on full feed

after the pasture season closed, ending the test for each lot when the average weight of the pigs of that lot was approximately 200 pounds. At that time the condition of the pigs was very satisfactory.

During the finishing period all lots had identical conditions and free access to a mixture of concentrates, consisting of 75 pounds of barley, 25 pounds of feed wheat, and 8 pounds of tankage in self-feeders.

This method gave more complete information on the relative economy of the different amounts of barley fed while the pigs were on forage, since it included a finishing period, giving complete data on growing pigs to a suitable market weight and finish.

PIGS USED

In this experiment, thirty pigs were divided into three equal lots at weaning time. The pigs were grade Poland Chinas, farrowed during the latter part of February and early March. At the time the experiment began—April 28th—the pigs averaged about 35 pounds in weight. During the course of the experiment, one pig in Lot I contracted pneumonia and was taken out. Corrections were made for the amount of feed eaten by this pig before its removal. The pigs were weighed every ten days. Individual weights were taken every twenty days.

PASTURE

The forage provided for these pigs consisted of a mixture of alfalfa, white clover, blue-grass, and timothy, with alfalfa predominating. Alfalfa had been seeded two years previously. These plots had been used for pig pasture during the preceding season.

FEEDING

The feed given in addition to the forage consisted of ground hull-less barley. Lots I, II, and III were given approximately 1, 2, and 3 pounds of barley per 100 pounds of live weight respectively. This was fed dry in two equal feeds given morning and evening. Water was kept before the pigs at all times.

PASTURE PERIOD

In Table II are given the results of the pasture period of this experiment. The average initial weight was 34.2 to 35 pounds and the average final weight was 111.6 pounds in the case of Lot I, 128.5 in Lot II, and 163.8 in Lot III, the respective lots making an

TABLE II—ALFALFA PASTURE

Pasture period—170 days

	Lot I	Lot II	Lot III
Barley fed daily per cwt................(lbs.)	1	2	3
Pigs in lot....................................	9	10	10
Amount of pasture.....................(acre)	0.75	0.75	0.75
Initial weight of lot....................(lbs.)	308.00	347.00	350.00
Average initial weight per pig.......... "	34.20	34.70	35.00
Final weight of lot...................... "	1004.00	1285.00	1638.00
Average final weight per pig........... "	111.60	128.50	163.80
Total gain by lot......................... "	696.00	938.00	1288.00
Average daily gain per pig.............. "	0.45	0.55	0.76
Total barley consumed.................. "	*931.50	2261.50	4054.00
Average daily ration per pig........... "	0.61	1.33	2.38
Barley per pound gain on pasture...... "	1.34	2.41	3.15

*Corrected for pig removed from lot.

average daily gain per pig of 0.45, 0.55, and 0.76 pound. The barley consumed per pound of gain was roughly proportional to the amount fed daily per 100 pounds live weight. However, the gains produced per acre were much higher in case of the lots that were fed larger amounts of grain, such lots requiring a smaller amount of pasture per pound of gain.

FINISHING PERIOD

Further results on the growing of swine for market on forage are obtained in a study of the gains and the feed consumed while the swine were being finished to a 200-pound weight. These data are given in Table III.

The average daily gains per head during this period were 1.96, 1.83, and 1.97 pounds respectively for lots I, II, and III. During this period the pigs were fed ground hull-less barley, ground feed wheat, and tankage in self-feeders. These feeds were mixed in the ratio of 75 pounds of ground barley and 25 pounds of ground feed wheat, supplemented with 8 pounds of tankage. The tankage was obtained from a Montana packing house. It contained about 42 per cent protein. It is shown in the table that these pigs, ranging from 111.6 to 163.6 pounds at the beginning and from 201.8 to 209.7 pounds at the end of the finishing period, ate 6⅔ to 7½ pounds of this mixture per head daily. The respective feed requirements for a pound of gain by lots I, II, and III during the finishing period were 3.82, 3.84, and 3.38 pounds. Lot III consumed the smallest amount of feed per head daily and also made the most economical

TABLE III—ALFALFA PASTURE

Finishing period

			Lot I	Lot II	Lot III
Pigs in lot			9	10	10
Time in feed lot (days)			50	40	20
Initial weight of lot		(lbs.)	1004.00	1285.00	1638.00
Average initial weight per pig		"	111.60	128.50	163.80
Final weight of lot		"	1887.00	2018.00	2032.00
Average final weight per pig		"	209.70	201.80	203.20
Total gain by lot		"	883.00	733.00	394.00
Average daily gain per pig		"	1.96	1.83	1.97
Total feed consumed	Barley	"	2344.10	1954.20	926.40
	Wheat	"	781.40	651.40	308.80
	Tankage	"	250.00	208.40	98.80
	Total	"	3375.50	2814.00	1334.00
Average daily ration per pig	Barley	"	5.21	4.89	4.63
	Wheat	"	1.74	1.63	1.55
	Tankage	"	0.55	0.52	0.49
	Total	"	7.50	7.04	6.67
Feed consumed per pound gain	Barley	"	2.65	2.67	2.35
	Wheat	"	0.89	0.89	0.78
	Tankage	"	0.28	0.28	0.25
	Total	"	3.82	3.84	3.38

gains on the feed eaten. It is to be noted also that the time required by Lot III to reach a weight of 200 pounds or over was thirty days less than was required by Lot I and twenty days less than was required by Lot II. This is oftentimes a factor of considerable importance in swine production, depending on the season and the fluctuation in prices.

SUMMARY OF THE 1915 EXPERIMENT

The real test of the value of any method of swine feeding is the economy of the practice when considered from the standpoint of the entire feeding period. In Table IV is given a summary of the results of the pasture and finishing periods.

In this experiment we find that the more liberal feeding while on pasture shortened the total feeding period, causing a maximum difference of thirty days. The average daily gain during the entire experiment was practically the same in lots I and II, but the daily gain per head by Lot III was practically 0.1 pound greater than the gains of lots I and II. This resulted from the greater average daily feed consumption by this lot. While Lot I consumed less feed per day than did Lot II, Lot I was able to maintain prac-

TABLE IV—ALFALFA PASTURE

Summary of entire experiment

			Lot I	Lot II	Lot III
Length of experiment (days)			220	210	190
Number of pigs in lot			9	10	10
Initial weight of lot		(lbs.)	308.00	347.00	350.00
Average initial weight per pig		"	34.20	34.70	35.00
Final weight of lot		"	1887.00	2018.00	2032.00
Average final weight per pig		"	209.70	201.80	203.20
Total gain by lot		"	1579.00	1671.00	1682.00
Average daily gain per pig		"	0.80	0.80	0.89
Total feed consumed*		"	4307.50	5075.50	5388.00
Average daily feed per pig*		"	2.18	2.42	2.84
Feed consumed per pound gain	Barley	"	2.08	2.52	2.96
	Wheat	"	0.49	0.39	0.18
	Tankage	"	0.16	0.13	0.06
	Total	"	2.73	3.04	3.20

*During the pasture period the pigs were fed crushed barley only. During the finishing period the feed consisted of a mixture of barley, wheat, and tankage. (See tables II and III.)

tically the same rate of gain by eating more forage and by making more rapid gains during the finishing period.

The feed consumed per pound of gain was influenced by the amount of barley fed while on pasture, the lot receiving the largest grain ration while on forage requiring the most concentrates for a pound of gain during the entire feeding period, and the lot receiving the smallest ration of grain while on pasture requiring the least concentrates per pound of gain. It will be noted, however, that the lots fed more heavily while on pasture required less feed during the finishing period and hence they required somewhat less of the supplements (see Table III), but the total concentrates required during the entire experiment were greater in those lots fed a larger grain ration while on pasture.

FINANCIAL STATEMENT FOR 1915

The results indicate that both in cost of concentrates and pasture required to produce 100 pounds of gain and in the return on labor and investment, the lot fed 1 pound of barley daily per 100 pounds live weight while on pasture gave most favorable results. Next in order came Lot II, fed 2 pounds of barley daily per 100 pounds live weight on pasture.

TABLE V—ALFALFA PASTURE

Financial statement

	Lot 1	Lot II	Lot III
Barley fed daily per cwt. (lbs.)	1	2	3
Cost of concentrates and pasture required to produce 100 lbs. gain	$9.09	$9.98	$10.40
Cost of barley	98.27	126.47	149.41
Cost of wheat	23.44	19.54	9.26
Cost of tankage	6.87	5.73	2.72
Cost of pasture	15.00	15.00	15.00
Initial cost of pigs	61.60	69.40	70.00
Total cost of concentrates, pasture and pigs	205.18	236.14	246.39
Final value of pigs	264.18	282.52	284.48
Returns on labor and investment			
Per lot	59.00	46.38	38.09
Per pig	6.56	4.64	3.81

Prices:—

Barley, $3 per 100 pounds.
Feed wheat, $3 per 100 pounds.
Tankage, $2.75 per 100 pounds or $55 per ton (including freight).
Pasture, $20 per acre (based on yield of hay).
Initial cost of pigs, $20 per 100 pounds.
Final value of pigs, $14 per 100 pounds.

All lots in this test gave a reasonable margin over the cost of concentrates and pasture at the prices given. It should be noted in this connection that the ratio of prices of grain and of finished hogs is quite narrow. The normal ratio is appreciably wider, but in spite of that fact the margins obtained in these tests are fairly liberal, due to the effectiveness of alfalfa pasture and to the rations fed.

EXPERIMENTS CONDUCTED IN 1916

In 1916 a third experiment was conducted by the authors to determine the most efficient grain ration to feed pigs while on medium red clover pasture. The plan of work was changed somewhat from that of previous years. This change consisted of adding two lots of pigs, one to have pasture without barley and the other to have free access to barley during the pasture period.

The plan of this experiment was as follows: Five lots of pigs were grazed upon medium red clover forage. During the pasture period, Lot I received daily 1 pound of ground hull-less barley per

Note.—Photographs of the pigs used in this experiment are shown in the last pages of the bulletin.

100 pounds live weight; Lot II, 2 pounds per 100 pounds live weight; Lot III, 3 pounds per 100 pounds live weight; Lot IV had access to barley at all times in a self-feeder; and Lot V was fed no grain. The pigs were placed on forage as early as the season would permit and continued on forage until the end of the growing season. After the grazing period closed, the lots were increased to full feed of a mixture of ground hull-less barley 100 pounds and tankage 8 pounds and fed with self-feeders. All lots were finished to a 200-pound market weight without redivision. The addition of the lot without grain and the lot fed a full grain ration while on forage gives much more complete data than those secured in the preceding years.

PIGS USED

The pigs used were pure-bred and grade Duroc Jerseys. The lots of pigs were made up as uniformly as possible with respect to breeding, thrift, weight, and so forth. At the beginning of the experiment there were nine pigs in each lot and the average initial weight per pig was from 27 to 30 pounds. One pig in Lot III died during the course of the experiment from an attack of acute indigestion. This was not in any way the direct result of the experimental conditions as none of the other pigs in the lot showed such a tendency. Two pigs in Lot V died during the course of the experiment because of the insufficiency of the clover pasture alone as feed for pigs of this age and size.

The pigs were weighed every ten days. Individual weights were taken every twenty days.

PASTURE

The forage consisted of medium red clover which had been seeded during the spring of 1915. A half-acre tract was provided for each lot of pigs. During the first part of the pasture period the pigs were confined to a quarter-acre area by portable hurdles, as this was sufficient for the needs of the pigs at this time. After the first cutting of hay was removed from the quarter-acre not pastured, the area allotted to the pigs was extended as needed.

FEEDING

One-half the daily grain allowance was fed to lots I, II, and III in the morning and the other half in the evening, while Lot IV had free access to grain at all times. The barley was fed dry. Water was provided in barrels equipped with automatic hog-waterers. The

barrels were cleaned every ten days in order to keep the water supply in good condition.

PASTURE PERIOD

The average initial weight of the pigs which lived through the experiment varied from 27.2 to 30 pounds. During the 90-day forage

TABLE VI—RED CLOVER PASTURE

Pasture period—90 days

	Lot I	Lot II	Lot III	Lot IV	Lot V
Barley fed daily per cwt.........(lbs.)	1	2	3	Self-fed	0
Number of pigs in lot.................	9	9	8	9	7
Acreage of pasture to time of first cutting—29 days	0.25	0.25	0.25	0.25	0.25
Acreage of pasture after first cutting—61 days	0.50	0.45	0.30	0.25	0.50
Number of pigs per acre.............	24	26	33	36	19
Initial weight of lot.............(lbs.)	257.7	245.7	233.3	251.7	210.3
Average initial weight per pig.... "	28.6	27.2	29.2	28.0	30.0
Final weight of lot .... "	385.5	499.0	538.0	846.5	259.5
Average final weight per pig..... "	42.8	55.4	67.3	94.1	37.1
Total gain by lot................ "	127.8	253.3	304.7	594.8	49.2
Average daily gain per pig...... "	0.16	0.31	0.42	0.73	0.078
Total barley consumed........... "	290.0	665.0	*963.0	2108.6	0
Average barley consumed daily per head .... "	0.36	0.82	1.34	2.60	0
Average barley consumed daily per cwt. .... "	0.98	1.93	2.80	4.37	0
Barley consumed per lb. gain.... "	2.27	2.63	3.16	3.55	0

*Corrected for feed consumed by pig which died during experiment.

TABLE VII—RED CLOVER PASTURE

Transitional period—30 days

	Lot I	Lot II	Lot III	Lot IV	Lot V
Number of pigs in lot..................	9	9	8	9	7
Initial weight of lot.............(lbs.)	385.50	499.00	538.00	846.50	259.50
Average initial weight per pig... "	42.80	55.40	67.30	94.10	37.10
Final weight of lot.............. "	623.00	749.00	776.00	1131.50	479.50
Average final weight per pig..... "	69.20	83.20	97.00	125.70	68.50
Total gain by lot................ "	237.50	250.00	238.00	285.00	220.00
Average daily gain per pig....... "	0.88	0.93	0.99	1.06	1.05
Total barley consumed........... "	452.50	663.00	746.40	1120.80	450.80
Average barley consumed daily per cwt.* .... "	3.04	3.70	3.84	3.82	4.23
Average barley consumed daily per pig .... "	1.68	2.46	3.11	4.15	2.15
Barley consumed per pound gain "	1.91	2.65	3.14	3.93	2.05

*The weight used in calculating the average barley consumed daily per 100 pounds live weight was an average of all the weights taken during the period.

period the gains varied in the same direction as the amounts of barley fed. The average daily gains per pig in the various lots were as follows: Lot I, 0.16 pound; Lot II, 0.31 pound; Lot III, 0.42 pound; Lot IV, 0.73 pound; and Lot V, 0.078 pound. Without additional feed of any kind, 30-pound pigs on clover pasture made only very small and unprofitable gains. The amount of barley consumed per pound of gain was greatest in those lots receiving the larger daily ration of barley. The acreage of pasture required, however, was less for those lots receiving more grain. Lot IV required only 0.25 acre during the whole season. The area pastured by the other lots was increased after the first cutting of hay was removed. The area required by lots I and V was finally 0.50 acre each, by Lot II, 0.45 acre, and by Lot III, 0.30 acre. In so far as the productive capacity in terms of hay was concerned, the average of the acreage used by each lot up to the time of the first cutting and that used after the first cutting would represent the amount used for the whole season. On the other hand, considering the acreage of clover that should be available for pasture during the season, the maximum area used by each lot during the entire pasture period should be taken as the guide.

TABLE VIII—RED CLOVER PASTURE

Combined pasture and transitional periods—120 days

		Lot I	Lot II	Lot III	Lot IV	Lot V
Number of pigs in lot		9	9	*8	9	**7
Acreage of pasture—29 days		0.25	0.25	0.25	0.25	0.25
Arceage of pasture—91 days		0.50	0.45	0.30	0.25	0.50
Average acreage of pasture		0.375	0.35	0.275	0.25	0.375
Initial weight of lot	(lbs.)	257.7	245.7	233.3	251.7	210.3
Average initial weight per pig	"	28.6	27.2	29.2	28.0	30.0
Final weight of lot	"	623.0	749.0	776.0	1131.5	479.5
Average final weight per pig	"	69.2	83.2	97.0	125.7	68.5
Total gain by lot	"	365.3	503.3	542.7	879.8	269.2
Average daily gain per pig	"	0.34	0.47	0.57	0.81	0.32
Total barley consumed	"	742.5	1328.0	†1709.40	3229.4	‡‡450.8
Average barley consumed daily per cwt.	"	1.67	2.53	3.17	4.16	‡‡1.42
Barley consumed per pound gain	"	2.03	2.64	3.15	3.67	‡‡1.67

*Nine pigs in lot originally. One died during course of experiment. Correction made for gains and feed consumed by this pig. (See Note †.)

**Nine pigs in lot originally. Two died during the pasture period.

†Corrected for feed consumed by pig which died August 4th on basis of live weight in proportion to feed consumed.

‡‡Fed grain during last 30 days only.

TRANSITIONAL PERIOD

The feeding of barley to Lot V was started at the beginning of the transitional period, and the rations were gradually increased until all lots were on full feed of barley. As the lots reached full ration they were fed by the use of a self-feeder.

In Table VIII is given a summary of the results obtained during the pasture and transitional periods of the experiment, covering 120 days. The gains while on pasture were greatly influenced by the amount of barley fed, and the amount of barley required in addition to the pasture for a pound of gain tends to vary with the amount fed. The amount of pasture required tends to vary in the opposite direction.

FINISHING PERIOD

During the finishing period all lots were fed with self-feeders in dry pens. The feed consisted of ground hull-less barley and tankage in the proportion of 100 pounds of barley to 8 pounds of tankage. The tankage contained 9.33 per cent of moisture, 44.39 per cent of protein, and 23.09 per cent of ash.* It was obtained from a Montana packing house.

The length of the finishing period varied from fifty to seventy-six days, according to the amount of grain fed to the pigs during the pasture period. Other things being equal, the quicker finish is more desirable, but the actual advantage or disadvantage really depends on the season and the condition of the market, as will be indicated later.

The average daily gain during this period was fairly uniform, with Lot I leading slightly. The amount of feed eaten per pound of gain was not greatly different, but the gains by lots I and IV were somewhat more economical, costing 27 to 48 cents less per 100 pounds than the gains by the other lots.

SUMMARY OF 1916 EXPERIMENT

The data on the separate periods bring out interesting and valuable facts, but from the standpoint of the producer of pork the results of the entire feeding period furnish the best indication of the value of any practice. In Table X is given a summary of results of the entire experiment.

*Analysis by Dr. M. J. Blish, of the Chemistry Department of the Montana Agricultural Experiment Station.

TABLE IX—RED CLOVER PASTURE

Finishing period

		Lot I	Lot II	Lot III	Lot IV	Lot V
Number of pigs		9	9	8	9	7
Length of period (days)		72	70	65	50	76
Barley eaten daily per cwt. during pasture period (90 days)	(lbs.)	0.98	1.93	2.80	*4.37	0
Initial weight of lot	"	623.00	749.00	776.00	1131.50	479.50
Average initial weight per pig	"	69.20	83.20	97.00	125.70	68.50
Final weight of lot	"	1809.50	1808.50	1638.50	1875.50	1404.00
Average final weight per pig	"	201.10	200.90	204.80	208.40	200.60
Total gain by lot	"	1186.50	1059.50	862.50	744.00	924.50
Average daily gain per pig	"	1.83	1.68	1.66	1.05	1.74
Total feed consumed — Barley	"	4157.20	3921.40	3138.70	2573.20	3386.90
Total feed consumed — Tankage	"	332.60	313.70	251.10	205.90	271.00
Total feed consumed — Total	"	4489.80	4235.10	3389.80	2779.10	3657.90
Feed consumed daily per cwt. — Barley	"	4.94	4.46	4.15	3.52	4.74
Feed consumed daily per cwt. — Tankage	"	0.40	0.36	0.33	0.28	0.38
Feed consumed daily per cwt. — Total	"	5.34	4.82	4.48	3.80	5.12
Average daily ration — Barley	"	6.42	6.22	6.04	5.72	6.37
Average daily ration — Tankage	"	0.51	0.50	0.48	0.46	0.51
Average daily ration — Total	"	6.93	6.72	6.52	6.18	6.88
Feed per pound of gain — Barley	"	3.50	3.70	3.64	3.46	3.67
Feed per pound of gain — Tankage	"	0.28	0.30	0.29	0 28	0.29
Feed per pound of gain — Total	"	3.78	4.00	3.93	3 74	3.96

*Fed all they would eat in a self-feeder.

TABLE X—RED CLOVER PASTURE

Summary

		Lot I	Lot II	Lot III	Lot IV	Lot V
Number of pigs in lot		9	9	8	9	7
Time required to reach weight of 200 pounds (days)		192	190	185	170	196
Barley consumed daily per cwt. during forage period proper (90 days)	(lbs.)	0.96	1.93	2.80	*4.37	0
Barley consumed daily per cwt. during transitional period (30 days)	"	3.04	3.70	3.84	3.82	4.23
Barley consumed daily per cwt. during the first 120 days	"	1.67	2.53	3.17	4.16	1.42
Initial weight of the lot	"	257.7	245.7	233.3	251.7	210.3
Average initial weight per pig	"	28.6	27.2	29.2	28.0	30.0
Final weight of lot	"	1809.5	1808.5	1638.5	1875.5	1404.0
Average final weight per pig	"	201.1	200.9	204.8	208.4	200.6
Total gain by lot	"	1551.8	1562.8	1405.2	1623.8	1193.7
Average daily gain per pig	"	0.90	0.91	0.95	1.06	0.87
Total feed consumed: Barley	"	4899.7	5249.4	4848.1	5802.6	3837.8
Total feed consumed: Tankage	"	332.6	313.7	251.1	205.9	271.0
Total feed consumed: Total	"	5232.3	5563.1	5099.2	6008.5	4108.8
Feed consumed per pound gain: Barley	"	3.16	3.36	3.45	3.57	3.21
Feed consumed per pound gain: Tankage	"	0.21	0.20	0.18	0.13	0.23
Feed consumed per pound gain: Total	"	3.37	3.56	3.63	3.70	3.44
Acreage of pasture: To time of first cutting—29 days		0.25	0.25	0.25	0.25	0.25
Acreage of pasture: After time of first cutting -91 days		0.50	0.45	0.30	0.25	0.50
Acreage of pasture: Average acreage		0.375	0.35	0.275	0.25	0.375

*Lot IV was fed all the barley the pigs would eat in a self-feeder.

Variations in the amount of barley fed to the pigs during the pasture period caused a maximum difference of twenty-six days in the time required to reach an average weight of 200 pounds. The concentrates required per pound of gain tended to vary in the same direction as the amount of barley fed to the pigs while on pasture. The amount required by Lot I was practically the same as was required by Lot V which was not fed grain on pasture.

The condition of the different lots varied somewhat. Lot IV had reached a more uniformly high condition at the 200-pound weight than the other lots. Lots II and III showed practically the same degree of finish while Lot I showed somewhat more uniformity and higher condition than the seven pigs of Lot V.

FINANCIAL STATEMENT FOR 1916

A financial statement is a valuable addition to the results of a feeding test because it reduces all factors of production to a common basis or to common units for measurement. However, prices vary greatly from season to season and from year to year. Prices vary also in different localities. The relations of the prices of different items vary from time to time; that is, the price of one feed may increase while that of another may remain about the same, or it may decrease. Prices of feeds may increase or decrease while the price of hogs remains about the same and vice versa. Any financial statement is therefore limited in its application and the results should be accepted for particular conditions only when the prices are found to be the same as those prevailing under the given conditions. For use in other cases, the financial statement should be recalculated, using the prices current at the time and place in which the results are to be applied.

In Table IX are given the cost of gains and the financial statement of the experiment conducted in 1916. The figures used are based on 1917 prices as they are considered much more applicable to present conditions. The rent of the pasture is based on the yield of hay. One-half the hay crop at $15 per ton is taken as a representative figure for the rent. The selling price of finished pigs is based on the Chicago average daily top prices, allowing a margin for cost of putting them on the market.

It will be noted that during the pasture period the cost of gains was greatest for lots I and V, which were fed a small amount of

grain or no grain during this period. At the prices given in connection with the table all lots would have been run at a loss if they had been sold at the end of the pasture period. The greatest loss per

TABLE XI—RED CLOVER PASTURE

Financial statement

	Lot I	Lot II	Lot III	Lot IV	Lot V
Barley fed daily per cwt. (lbs.)......	1	2	3	Self-fed	0
Pasture period					
Cost of barley and pasture required to produce 100 lbs. gain.............	$14.14	$11.33	$11.74	$11.69	$19.04
Cost of barley consumed..............	8.70	19.95	28.89	63.26	0.00
Cost of pasture.......................	9.37	8.75	6.87	6.25	9.37
Initial cost of pigs....................	51.54	49.14	46.66	50.34	42.06
Total cost of barley, pasture, and pigs	69.61	77.84	82.42	119.85	51.43
Final value of pigs....................	50.11	64.87	69.94	110.04	33.73
Returns on labor and investment					
Per lot	-19.50	-12.97	-12.48	-9.81	-17.70
Per pig	-2.17	-1.44	-1.56	-1.09	-2.53
Finishing period					
Cost of barley and tankage required to produce 100 lbs. gain..........	11.28	11.92	11.72	11.14	11.80
Cost of barley consumed..............	124.72	117.64	94.16	77.20	101.61
Cost of tankage consumed............	9.15	8.63	6.91	5.66	7.45
Initial cost of pigs....................	80.99	97.37	100.88	147.09	62.33
Total cost of feed and pigs..........	214.86	223.64	201,95	229.95	171.39
Final value of pigs..................	253.33	253.19	229.39	262.57	196.56
Returns on labor and investment					
Per lot	38.47	29.55	27.44	32.62	25.17
Per pig	4.27	3.28	3.43	3.62	3.00
Total experiment					
Cost of barley, tankage, and pasture per 100 lbs. gain.................	10.67	11.18	11.33	11.45	11.05
Cost of total barley consumed.......	146.99	157.48	145.44	174.08	115.13
Cost of total tankage consumed......	9.15	8.63	6.91	5.66	7.45
Cost of pasture......................	9.37	8.75	6.87	6.25	9.37
Initial cost of pigs....................	51.54	49.14	46.66	50.34	42.06
Total cost of barley, tankage, pasture, and pigs	217.05	224.00	205.88	236.33	174.01
Value of finished hogs................	253.33	253.19	229.39	262.57	196.56
Returns on labor and investment					
Per lot	36.28	29.19	23.51	26.24	22.55
Per pig	4.03	3.24	2.94	2.92	3.22

Prices:

Barley, $3 per 100 pounds.

Tankage, $2.75 per 100 pounds (including freight).

Pasture, $25 per acre (one-half hay crop at $15 per ton).

Initial cost of pigs, $20 per 100 pounds.

Value of pigs at close of pasture period or at the beginning of the finishing period, $13 per 100 pounds.

Value of finished hogs, $14 per 100 pounds.

head would have resulted in those lots fed small amounts of grain or no grain during this period.

During the finishing period, however, the cost of gains was not quite so high in general, and all lots gave a margin over and above the cost of the feed. At the prices given this margin varied from $3.28 to $4.27 per head. It is seen that the showing during the finishing period is more favorable than during the pasture period. In this connection it should be noted that at the beginning of the pasture period the price per pound for pigs was seven cents higher than the value at the end of the pasture season. On the other hand, the value of the pigs at the end of the finishing period was one cent per pound greater than at the beginning of the period. In general it will be found that it is an unprofitable operation to take pigs at weaning time at a high value per pound, carry them along for a period in thin condition, and sell them when too small to bring a figure that approaches the top market price. There is a much better chance for profit if the pigs are finished for market. On the other hand, the feeding of partly grown, healthy, vigorous pigs in thin condition bought below the price per pound for which they can be sold when finished should be a profitable venture.

From Table XI it may be seen that all lots furnished a margin to apply on the labor, investment, and profits of the enterprise. The widest margin per head was obtained in Lot I which was fed 1 pound of ground hull-less barley daily per 100 pounds of live weight during the pasture period. The margin in the case of the other lots was approximately the same. It should be noted that Lot V was not debited with the pigs which died owing to the insufficiency of clover pasture only for pigs of this size and age. The other pigs in this lot were in very thin condition at the end of the pasture period and evidently some of them would not have survived much longer. If this loss had been taken into consideration this lot would have given returns over and above cost of concentrates and pasture of $2 per head instead of $3.22 as given in the table.

In many comparative tests of this character there is a tendency to lay considerable stress on the so-called "profits per acre of forage." These are obtained by crediting all returns in excess of the cost of feed and the original cost of the pigs to the forage. Only the results obtained during the pasture period can be used in this

connection. If the feeding of barley is done at a profit, it is perfectly obvious that the self-fed lot would show much more favorable results than those lots fed lighter grain rations, because of the more extensive operations conducted on a given area. For most favorable results per acre such methods of study would probably indicate the feeding of large numbers of hogs on small areas regardless of the amount of forage the hogs would obtain. Owing to this fallacy, returns per acre calculated on this basis are not included in the report of this test since they would only be misleading.

EXPERIMENTS CONDUCTED IN 1917

In 1917 another series of tests was conducted on very much the same plan and with the same objects in view as those of the 1916 tests. The chief point of difference consisted in the admixture of timothy in the pasture, making the pasture mixed clover and timothy with the clover predominating. The pigs were also slightly larger, averaging 38 pounds per head at the beginning of the test. This test was also conducted by the authors.

PASTURE PERIOD

In Table XII are given the results obtained during the pasture period.

The number of pigs per lot at the beginning of the test was nine. In this test one pig of Lot V died as a result of undernourishment on

TABLE XII—RED CLOVER PASTURE

Pasture period—110 days

	Lot I	Lot II	Lot III	Lot IV	Lot V
Barley fed daily per cwt........(lbs.)	1	2	3	Self-fed	0
Number of pigs in lot...............	9	9	9	9	7
Amount of pasture (acres)..........	0.60	0.58	0.53	0.40	0.58
Number of head per acre					
First part of season--20 days....	36	36	36	36	27
Second part of season—90 days..	13	15	16	21	12
Average for total pasture season	15	16	17	23	13
Initial weight of lot...........(lbs.)	345	351	349	346	266
Initial weight per head........ "	38	39	39	38	38
Final weight of lot............ "	532	689	937	1103	372
Final weight per head.......... "	59	77	104	123	53
Total gain by lot.............. "	187	338	588	757	106
Average daily gain per head... "	0.20	0.34	0.60	0.76	0.14
Total barley eaten............. "	464.60	1067.30	1892.60	3327.10	0
Average daily rations per head "	0.47	1.08	1.91	3.36	0
Barley eaten per pound gain... "	2.48	3.16	3.22	4.40	0

pasture alone. Another pig was removed from this lot as a result of conditions wholly foreign to the experiment. It will be recalled that in the 1916 test there was loss of two pigs in the lot on pasture only because of undernourishment. This seems to be characteristic of this method of handling pigs of this size and age.

It is noted that a considerably larger acreage of pasture is required late in the pasture period than during the first part of the period, especially by those lots on light grain rations or by the lot fed no grain. The amount of pasture required depended on the amount of grain fed, most being needed by those lots receiving no grain or small rations of grain and the pasture requirement decreasing as the grain ration was increased.

The daily gains depended on the amount of grain fed, being lowest in Lot V on pasture only and increasing as the allowance of grain was increased. Comparing lots I to IV, the barley consumed per pound of gain was least in Lot I and increased as the grain ration was increased.

TRANSITIONAL PERIOD

When the growth of pasture began to decrease to such an extent that it did not meet the full requirement of the pigs, the grain ration was gradually increased until at the end of twenty days or less, depending on the amount of grain fed during the pasture period, the pigs were on full feed of barley. Three or four days before the end of this period it was found necessary to remove the pigs from the pasture lots to dry pens.

TABLE XIII—RED CLOVER PASTURE

Transitional period, 20 days

		Lot I	Lot II	Lot III	Lot IV	Lot V
Barley fed daily per cwt. during pasture period	(lbs.)	1	2	3	Self-fed	0
Number of pigs in lot		9	9	9	9	7
Initial weight of lot	"	532	689	937	1103	372
Initial weight per head	"	59	77	104	123	53
Final weight of lot	"	681	854	1144	1245	506
Final weight per head	"	76	95	127	138	72
Total gain by lot	"	149	165	207	142	134
Average daily gain per head	"	0.83	0.90	1.15	0.79	0.91
Amount of barley eaten	"	392	481	745.50	750.40	306.80
Average daily ration per head	"	2.18	2.67	4.19	4.17	2.19
Barley eaten per pound gain	"	2.63	2.92	3.64	5.28	2.29

It is noticeable that those lots on light grain ration during the pasture period tended to gain more rapidly during the transitional period; also that the amount of barley required for a pound of gain was less in those lots receiving light grain rations during the pasture period.

FINISHING PERIOD

Without any redivision of the lots these pigs were continued through a finishing period until they had reached an average weight of approximately 200 pounds. During this period all lots were fed by use of the self-feeder. Tankage was used as the supplement, making the ration consist of ground hull-less barley 100 parts and tankage 8 parts by weight. It should be noted that the tankage used was made in Montana and that the cost, therefore, was not to be compared with that of tankage made in St. Paul, Chicago, and other distant points. The analysis of this tankage indicated 44.5 per cent of protein and 23 per cent of ash. In comparative tests this tankage has been found to be one of the most satisfactory supplements among those readily available in this section.

The results of the finishing period are given in Table XIV. The

TABLE XIV—RED CLOVER PASTURE

Finishing period

		Lot I	Lot II	Lot III	Lot IV	Lot V
Barley fed daily per cwt. during pasture period (lbs.)		1	2	3	Self-fed	0
Number of pigs in lot		9	9	9	9	7
Length of finishing period (days)		80	70	48	40	80
Initial weight of lot	(lbs.)	681	854	1144	1245	506
Initial weight per head	"	76	95	127	138	72
Final weight of lot	"	1838	1883	1840	1829	1380
Final weight per head	"	204	209	204	203	197
Total gain by lot	"	1157	1029	696	584	874
Average daily gain per head	"	1.61	1.63	1.61	1.62	1.56
Total feed eaten						
Barley	"	4355.60	3982.70	2854.20	2111.10	3454.60
Tankage	"	348.40	318.60	228.30	168.90	276.40
Total	"	4704.00	4301.30	3082.50	2280.00	3731.00
Average daily ration per pig						
Barley	"	6.05	6.32	6.61	5.86	6.17
Tankage	"	.48	.51	.53	.47	.49
Total	"	6.53	6.83	7.14	6.33	6.66
Feed eaten per pound gain						
Barley	"	3.77	3.87	4.10	3.61	3.95
Tankage	"	.30	.31	.33	.29	.32
Total	"	4.07	4.18	4.43	3.90	4.27

length of this period varied from forty to eighty days, depending on the amount of barley fed during the pasture period. The average daily gain was practically the same for all lots, the extreme variation being from 1.56 to 1.63 pounds. The average daily ration varied from 6.33 to 7.14 pounds, and the feed consumed per pound of gain from 3.90 to 4.43 pounds. There seemed to be no close relation between the amount of barley fed during the pasture period and any of these factors of the finishing period except the length of time required to reach a 200-pound average weight.

SUMMARY OF 1917 EXPERIMENT

The best measure of the merit of these practices is obtained from the summarized data of all the periods of the tests, representing the growing of the pigs from weaning time to a suitable market weight and condition. These data are given in Table XV.

The total time required to reach an average weight of approximately 200 pounds, the amount of pasture required, and the average daily gains were directly dependent on the amount of grain fed dur-

TABLE XV—RED CLOVER PASTURE

Summary of entire experiment

	Lot I	Lot II	Lot III	Lot IV	Lot V
Barley fed daily per cwt. during pasture period (lbs.)............	1	2	3	Self-fed	0
Number of pigs in lot..............	9	9	9	9	7
Time required to reach 200-pound weight (days)	210	200	178	170	210
Average pasture required (acre)....	0.00	0.58	0.53	0.40	0.58
Initial weight of lot............(lbs.)	345	351	349	346	266
Initial weight per head........ "	38	39	39	38	38
Final weight of lot.............. "	1838	1883	1840	1829	1380
Final weight per head.......... "	204	209	204	203	197
Total gain by lot.............. "	1493	1532	1491	1483	1114
Average daily gain per head.... "	0.79	0.85	0.93	0.97	0.76
Total feed eaten					
Barley .... "	5212.20	5631.00	5501.30	6188.60	3761.40
Tankage .... "	348.40	318.60	228.30	168.90	276.40
Total .... "	5560.60	5849.60	5729.60	6357.50	4037.80
Average daily ration					
Barley .... "	2.76	3.07	3.44	4.05	2.56
Tankage .... "	.18	.18	.14	.11	.19
Total .... "	2.94	3.25	3.58	4.16	2.75
Feed eaten per pound gain					
Barley .... "	3.49	3.61	3.69	4.18	3.37
Tankage .... "	.23	.21	.15	.11	.25
Total .... "	3.72	3.82	3.84	4.29	3.62

TABLE XVI—RED CLOVER PASTURE

Financial statement

	Lot I	Lot II	Lot III	Lot IV	Lot V
Barley fed daily per cwt. during pasture period (lbs.)	1	2	3	Self-fed	0
Pasture period					
Cost of barley and pasture required to produce 100 lbs. gain	$13.87	$12.91	$11.46	$14.24	$10.94
Cost of barley consumed	13.94	32.02	56.78	99.81	0.00
Cost of pasture	12.00	11.60	10.60	8.00	11.60
Initial cost of pigs	69.00	70.20	69.80	69.20	53.20
Total cost of barley, pasture, and pigs	94.94	113.82	137.18	177.01	64.80
Final value of pigs	69.16	89.57	121.81	143.39	48.36
Returns on labor and investment					
Per pig	-2.86	-2.69	-1.71	-3.74	-2.35
Per lot	-25.78	-24.25	-15.37	-33.62	-16.44
Finishing period					
Cost of feed required to produce 100 lbs. gain	12.12	12.46	13.21	11.64	12.73
Cost of barley consumed	130.67	119.48	85.63	63.33	103.64
Cost of tankage consumed	9.58	8.76	6.28	4.64	7.60
Initial cost of pigs	88.53	111.02	148.72	161.85	65.78
Total cost of barley, tankage, and pigs	228.78	239.26	240.62	229.82	177.02
Final value of finished hogs	257.32	263.62	257.60	256.06	193.20
Returns on labor and investment					
Per lot	28.54	24.36	16.98	26.24	16.18
Per pig	3.17	2.71	1.89	2.92	2.31
Total experiment					
Cost of barley, tankage, and pasture per 100 lbs. gain	11.92	12.16	12.20	13.37	11.85
Cost of barley consumed	156.37	165.93	165.04	185.66	112.84
Cost of tankage consumed	9.58	8.76	6.28	4.64	7.60
Cost of pasture	12.00	11.60	10.60	8.00	11.60
Initial cost of pigs	69.00	70.20	69.80	69.20	53.20
Total cost of barley, tankage, pasture, and pigs	246.95	256.49	251.72	267.50	185.24
Final value of pigs	257.32	263.62	257.60	256.06	193.20
Returns on labor and investment					
Per lot	10.37	7.13	5.88	-11.44	7.96
Per pig	1.15	.79	.65	-1.27	1.14

Prices:

- Barley, $3 per 100 pounds.
- Tankage, $2.75 per 100 pounds (including freight).
- Pasture, $20 per acre.
- Cost of pigs at weaning time, $20 per 100 pounds.
- Value of pigs at close of pasture period or at the beginning of the finishing period, $13 per 100 pounds.
- Value of finished pigs, $14 per 100 pounds.

ing the pasture period. It will be noted that the greatest amount of barley per pound of gain was required by those lots fed the largest amounts of barley during the pasture period. On the other hand, somewhat smaller amounts of tankage were required by these lots. The total feed requirement, however, was greater in the lots on heavy grain rations while on pasture.

FINANCIAL STATEMENT

In Table XVI are given financial statements of this test. The figures used are based on 1917 prices and costs. The pasture is rated at $20 per acre, which is equivalent to one-half the hay crop at $15 per ton.

As in the 1916 test, the pasture period when considered alone was not successful from the standpoint of the financial returns at the prices used in this connection, taking into consideration all lots. On the other hand, the returns during the finishing period were fairly satisfactory. The greater success of the finishing period is due to the spread between the initial and final prices per pound, while during the pasture period the initial price was considerably above the final price per pound. It will be noted that the costs of concentrates and pasture were about the same in the two periods if all lots are considered.

Considering the whole experiment, the cost of concentrates and pasture per 100 pounds gain was somewhat lower for those lots fed smaller amounts of grain or no grain during the pasture period. At the prices given the self-feeder lot was fed at a loss and the other lots gave only a small return on the labor and investment. If Lot V were debited with the loss of one pig, the margin in the case of this lot would be practically nothing.

EXPERIMENT CONDUCTED IN 1918

In 1918 an experiment was conducted to compare different methods of feeding on red clover pasture. Comparison was made between feeding 1 pound of ground hull-less barley per head daily and 1 pound per 100 pounds live weight daily, the latter being the method which gave the most economical results in previous tests. The results of the pasture period are given in Table XVII.

The pasture requirement was slightly less for Lot I, fed 1 pound of barley per head daily, and the gains somewhat more rapid. The amount of barley eaten per pound of gain was also greater for Lot I,

while the cost of gains was somewhat higher. The greater total gains by this lot resulted in returns per head which were approximately equal in the two cases. These lots of pigs were finished without redivision by self-feeding on barley and tankage at the close of the pasture and transitional periods. In tables XVIII, XIX, and

TABLE XVII—RED CLOVER PASTURE

Pasture period

		Lot I	Lot II
Barley fed daily		1 lb. per head	1 lb. per cwt.
Length of pasture period (days)		90	90
Number of pigs in lot		10	8
Acreage of pasture required			
Before first cutting		0.25	0.25
After first cutting		.75	.75
Average for season		.50	.50
Average number of pigs per acre		20	16
Initial weight of lot	(lbs.)	479	403
Initial weight per head	"	48	50
Final weight of lot	"	866	654
Final weight per head	"	87	82
Total gains of lot	"	387	251
Average daily gains per head	"	0.43	0.35
Total barley eaten	"	900	*439.50
Average daily ration of barley per head	"	1	0.61
Barley eaten per pound of gain	"	2.33	1.75

*Two pigs removed from lot. The feed deducted on account of the removal of No. 7 was 7.7 pounds, one-half the proportional share. The feed deducted on account of the removal of No. 9 was 47 pounds, the full proportional share to the time of removal. No. 7 gradually went down in condition.

TABLE XVIII—RED CLOVER PASTURE

Transitional period

		Lot I	Lot II
Barley fed daily during pasture period		1 lb. per head	1 lb. per cwt.
Length of transitional period (days)		20	20
Number of pigs in lot		10	8
Initial weight of lot	(lbs.)	866	654
Initial weight per head	"	87	82
Final weight of lot	"	1071	839
Final weight per head	"	107	105
Total gain by lot	"	205	185
Average daily gain per head	"	1.02	1.16
Total barley eaten	"	620	545.4
Average daily ration of barley per head	"	3.10	3.41
Barley eaten per pound gain	"	3.02	2.95

XX are given the respective data relative to the transitional and finishing periods and the summarized data for the entire test.

In neither case was the method of feeding on pasture such as to retard the rate of gain during the finishing period or to increase above normal the requirement of feed for producing gains as indi-

TABLE XIX—RED CLOVER PASTURE

Finishing period

		Lot I	Lot II
Barley fed daily during pasture period		1 lb. per head	1 lb. per cwt.
Length of finishing period (days)		40	47
Number of pigs in lot		10	8
Initial weight of lot	(lbs.)	1071	839
Initial weight per pig	"	107	105
Final weight of lot	"	1997	1630
Final weight per pig	"	200	204
Total gain by lot	"	926	791
Average daily gain per head	"	2.31	2.10
Total feed eaten			
Barley	"	3090.70	2731.50
Tankage	"	247.30	218.50
Total	"	3338.00	2950.00
Feed eaten per pound gain			
Barley	"	3.34	3.45
Tankage	"	.26	.28
Total	"	3.60	3.73

TABLE XX—RED CLOVER PASTURE

Summary

		Lot I	Lot II
Barley fed daily during pasture period		1 lb. per head	1 lb. per cwt.
Length of experiment (days)		150	157
Number of pigs in lot		10	8
Acreage of pasture required		0.50	0.50
Average number of pigs per acre		20	16
Initial weight of lot	(lbs.)	479	403
Initial weight per head	"	48	50
Final weight of lot	"	1997	1630
Final weight per head	"	200	204
Total gain by lot	"	1518	1227
Average daily gain per head	"	1.01	0.98
Total feed eaten			
Barley	"	4610.70	3716.40
Tankage	"	247.30	218.50
Total	"	4858.00	3934.90
Feed eaten per pound gain			
Barley	"	3.04	3.03
Tankage	"	.16	.18
Total	"	3.20	3.21

TABLE XXI—RED CLOVER PASTURE

Financial statement

	Lot I	Lot II
Barley fed during pasture period	1 lb. per head	1 lb. per cwt.
Cost of 100 pounds gain	$10.33	$10.44
Initial cost of pigs	95.80	90.60
Cost of pasture required	10.00	10.00
Value of barley eaten	138.32	111.49
Value of tankage eaten	8.42	6.55
Total cost of pigs, pasture, and feed	252.54	208.64
Selling value of finished hogs	279.58	228.20
Returns on labor and investment		
Per lot	27.04	19.56
Per pig	2.70	2.44

Prices:
- Barley, $3 per 100 pounds.
- Tankage, $3 per 100 pounds.
- Clover pasture, $20 per acre.
- Blue-grass and white clover pasture, $15 per acre.
- Initial cost of pigs, $20 per 100 pounls.
- Selling value of finished hogs, $14 per 100 pounds.

cated in Table XIX. The time required to finish the two lots was not widely different. Although these pigs were fed only a light grain ration during the pasture period, they were grown to a weight of 200 pounds at the age of seven to eight months.

The pasture requirement per pig as seen in Table XXI was slightly greater for Lot II. The feed requirement per pound of gain was practically the same for both lots.

In Table XXI is given a financial statement of this test. The difference here also is very small. Both in the cost of gains and in the returns on labor and investment the results were slightly in favor of the lot fed 1 pound of barley per head during the pasture period. While the results are not conclusive they indicate that the feeding of 1 pound of barley per head daily will give results which are at least as favorable as those obtained by feeding 1 pound of barley daily per 100 pounds of live weight.

RECAPITULATION

In general there is not a very wide difference in the results obtained from the different methods of feeding these lots. All tests. including those on alfalfa pasture, seem to indicate that feeding 1 pound of ground hull-less barley daily per 100 pounds of live weight during the pasture period gave most economical gains under the

system described in this report. It should be noted, however, that during the finishing period the grain was supplemented with tankage. If the supplement were not used these results probably would not apply. It should be borne in mind that the lighter grain ration on pasture necessitates a longer finishing period to bring the hogs up to a suitable market weight and finish. The preliminary test in feeding 1 pound of barley per head daily on clover pasture gave very favorable results.

Carrying pigs on pasture without grain from weaning time can not be recommended. Pigs handled in this manner gained very slowly and sometimes not at all. They became very thin, and if this method of handling extended over a very long period they were scarcely able to survive the treatment. Some of the pigs which did survive were permanently stunted. While the lots fed light grain rations during the pasture period became quite thin in condition, they never appeared to be underfed to such an extent as to endanger their future development. All pigs fed in this manner developed into very satisfactory market hogs after a suitable period on full feed.

The prices given for barley, pasture, and pigs gave a rather small margin between costs and gross returns, but if carefully fed there was a small margin to represent the profits of the business. It should be noted, however, that the price allowed for pigs at weaning time was large enough to pay a moderate profit on this phase of pork production. If pigs are produced by the man who finishes them, there is a chance for two profits on the operation.

In a comparison of the results obtained on alfalfa and clover pastures, either when reasonably pure or when mixed with more or less of grasses, the alfalfa appears to give somewhat more favorable results. The season for alfalfa pasture is slightly longer and its feeding value seems to be somewhat higher.

Miscellaneous Forage Crops for Swine

In 1915 an experiment was conducted by C. N. Arnett and R. R. Dodderidge for the purpose of testing the relative values of some annual forage crops for swine. Those tested were rape, barley, a mixture of rape and oats, and oats.

PIGS USED

The pigs used in this experiment were cross-bred Yorkshire-

Poland Chinas, pure-bred Duroc Jerseys, and grade Poland Chinas. They were divided into four lots of seven pigs each in such a way as to make the lots as much alike as possible with respect to weight, age, thrift, and breeding. During the experiment the pigs were weighed at intervals of fifteen days.

PASTURE

The forage consisted of one-half acre each of Dwarf Essex rape, Success barley, a mixture of Swedish Select oats and Dwarf Essex rape, and Swedish Select oats. These crops were sowed April 28th and the pigs were put on the pastures June 23d. The rape was sowed at the rate of 10 pounds per acre, the barley and the oats at the rate of 100 pounds per acre, and the mixture of oats and rape at the rate of 80 pounds of oats and 10 pounds of rape.

FEEDING

The pigs in all lots were fed approximately 2 pounds of ground hull-less barley per 100 pounds of live weight daily. This ration was fed dry in two equal parts, one in the morning and one in the evening. The pigs were watered twice daily.

RESULTS

The results of this experiment are given in Table XXII.

It will be seen that the pasture season on rape and on rape and oats was longest, furnishing pasture twenty-three days longer than either barley or oats and practically as late in the fall as alfalfa. At the beginning of the experiment the average weight of the pigs was

TABLE XXII.—COMPARISON OF ANNUAL PASTURE CROPS

		Lot IV	Lot V	Lot VI	Lot VII
		Rape pasture	Barley pasture	Rape and oats pasture	Oats pasture
Number of pigs in lot		7	7	7	7
Size of lot (acre)		0.50	0.50	0.50	0.50
Number of days on pasture		100	77	100	77
Initial weight of lot	(lbs.)	362	360	362	362
Initial weight per pig	"	51.70	51.40	51.70	51.70
Final weight of lot	"	743	586	661	616
Final weight per pig	"	106.10	83.70	94.40	88
Total gain by lot	"	381	226	299	254
Average daily gain per pig	"	0.54	0.42	0.43	0.47
Total barley consumed by lot	"	1008	691.50	939	714
Average daily grain ration	"	1.44	1.28	1.34	1.32
Barley consumed per pound gain	"	2.65	3.06	3.14	2.81

51 to 52 pounds. The average weight at the close was from 83.7 to 106.1 pounds, varying with the length of the period and the kind of pasture. The lot on rape pasture made the largest daily gains per head; the lot on oat pasture was second, while the lots on barley and on mixed oats and rape made practically the same average daily gains. The barley consumed per pound of gain was least for Lot IV on rape pasture, second for Lot VII on oat pasture, and about the same for Lot V on barley pasture and Lot VI on mixed oat and rape pasture.

FINANCIAL STATEMENT

In Table XXIII is given the cost of gains produced on the different kinds of pasture and the returns on the investment in the pigs and equipment and on the labor of feeding and caring for the pigs. The figures used are based on 1917 prices as these are considered more nearly applicable to present conditions. The variations in the cost of the pasture are due primarily to differences in the cost of seed and seeding. The rent of land and the cost of preparing the land for seeding are the same in all cases.

TABLE XXIII—ANNUAL PASTURE CROPS

Financial statement

	Lot IV	Lot V	Lot VI	Lot VII
	Rape pasture	Barley pasture	Rape and oats pasture	Oats pasture
Barley fed daily per cwt. (lbs.)........	2	2	2	2
Cost of barley and pasture required for 100 lbs. gain........................	$10.36	$13.CO	$12.93	$12.37
Total cost of barley consumed..........	30.24	20.74	28.17	21.42
Cost of pasture (0.5 acre)..............	9.25	10.00	10.50	10.00
Initial cost of pigs....................	57.92	57.60	57.92	57.92
Total cost of barley, pasture, and pigs.	97.41	88.34	96.59	89.34
Selling value of pigs at close of test....	96.59	76.18	85.93	80.08
Returns on labor and investment				
Per lot	-0.82	-12.16	-10.66	-9.26
Per pig	-0.12	-1.74	-1 52	-1.32

Prices:

Barley, $3 per 100 pounds.
Rape pasture, $18.50 per acre.
Barley pasture, $20 per acre.
Mixed rape and oats pasture, $21 per acre.
Oats pasture, $20 per acre.
Initial value of pigs, $16 per 100 pounds.
Final value of pigs, $13 per 100 pounds.

The most favorable showing was made by the lot on rape pasture. The cost of barley and pasture required to produce 100 pounds of gain was $10.36 for this lot at the prices given, while the costs for the other lots ranged from $12.37 to $13.60. The most unfavorable showing was made by the pigs in the barley lot. In returns on the labor and investment all lots show a loss. The smallest loss was sustained on the pigs in the rape lot, while the largest resulted on the pigs in the barley lot. It should be noted that the estimated initial value of the pigs was 16 cents per pound, while the estimated value at the end of the feeding period was 13 cents per pound. These estimates are based on a value of 14 cents per pound for finished hogs. Considering the cost of production, young pigs of 50 pounds weight or less are worth more per pound than finished hogs. On the other hand, stock that is partly grown and in thin condition, as were these pigs at the end of the test, sells for a lower price per pound than hogs of a suitable market weight and condition. Owing to the reduction in the price per pound of the pigs at the end of the test in comparison with the beginning, all lots show a loss on the operation. On the other hand, in case only of the lot on barley pasture was the cost of barley and pasture required to produce 100 pounds of gain greater than the final estimated value per 100 pounds. The costs for the other lots ranged from practically the same as the final estimated value down to $10.36, or $2.64 less than the final value.

EXPERIMENTS CONDUCTED IN 1917

In 1917 the authors conducted a series of comparative tests of different kinds of pasture for pigs. The pastures used in this case were red clover, sweet clover, and rape. The first cutting of hay was taken off the red clover plots before pasturing was begun. The sweet clover consisted of new seeding and therefore was suitable for pasture only from about the first of July until the end of the growing season.

The pigs used in this test were Duroc Jerseys, Berkshires, and cross-bred Berkshire-Duroc Jerseys. They were uniform in thrift, age, and size at the beginning of the test. Thirty-three pigs were divided into three lots of eleven pigs each, special attention being given to size, breeding, and thrift in order to make the lots as nearly equal as possible.

RESULTS

The results of this test are given in Table XXIV.

The length of the pasture period was the same for all lots. It should be noted that the pigs were turned into the rape plot as soon as it was of sufficient size to use for pasture. The sweet clover was seeded in the spring and pastured as soon as it had attained sufficient growth, while the red clover was seeded in 1916, cut for the first crop of hay in 1917, and pastured from the time the second crop was well started. Hence the rape was pastured during the full productive season, and the sweet clover and the red clover during only a part of the normal productive season of an established crop.

The carrying capacity of the red clover proved to be somewhat greater than that of the sweet clover or the rape. The average daily gains were practically the same on red clover and on rape while on sweet clover the gains were much slower.

The average daily ration was the same per 100 pounds of live weight but owing to the slower rate of gain on sweet clover the daily ration per head for this lot was less. The barley consumed per pound of gain was about the same for the red clover and the rape lots, while it was much greater for the sweet clover lot.

TABLE XXIV—RED CLOVER, SWEET CLOVER, AND RAPE PASTURE

		Lot I	Lot II	Lot III
		Red clover pasture	Sweet clover pasture	Rape pasture
Hull-less barley fed daily per cwt. (lbs.)...		2	2	2
Number of pigs in lot......................		11	11	11
Length of pasture season (days)...........		*80	**80	80
Amount of pasture (acre)...................		0.40	0.50	0.50
Number of head per acre....................		27	22	22
Initial weight of lot......................	(lbs.)	377	371	373
Initial weight per head....................	"	34	34	34
Final weight per lot.......................	"	712	558	690
Final weight per head......................	"	65	51	64
Total gain by lot..........................	"	335	187	326
Average daily gain per head................	"	0.38	0.21	0.37
Total barley eaten.........................	"	713	634	724
Average daily ration per head..............	"	0.81	0.72	0.82
Barley eaten per pound gain................	"	2.13	3.39	2.22

*Pastured only after first cutting of hay was taken off.
**New seeding of sweet clover.

The showing as indicated by these data is much less satisfactory in the case of sweet clover than in the case of either red clover or rape. Although the sweet clover was pastured during the same year in which it was seeded, it appeared to be in ideal condition for hog pasture as the growth was thick and fine when the pigs were turned in. The sweet clover was not readily eaten by the pigs. The second crop of red clover and the rape pasture proved about equally effective as pasture for pigs.

FINANCIAL STATEMENT

In Table XXV is given a financial statement of the results of this test.

Red clover and rape made decidedly the better showing in this test, while sweet clover did not give very favorable results.

Considering the prices of barley and pasture, the cost of 100 pounds of gain was very moderate in the red clover and rape lots. The cost of gains in the sweet clover lot was a trifle over $13 per 100 pounds, the estimated value of half-grown pigs in thin condition.

All lots showed a loss on the operation, due to the comparatively small gains and the lower value per pound allowed for the pigs at

TABLE XXV—RED CLOVER, SWEET CLOVER, AND RAPE PASTURE

Financial statement

	Lot I	Lot II	Lot III
	Red clover pasture	Blue-grass and white clover pasture	
Hull-less barley fed daily per cwt. (lbs.)...	2	2	2
Cost of barley and pasture required to produce 100 lbs. gain	$8.18	$13.18	$9.50
Cost of barley consumed	21.39	19.02	21.72
Cost of pasture	6.00	5.62	9.25
Initial cost of pigs	75.40	74.20	74.60
Total cost of barley, pasture, and pigs	102.79	98.84	105.57
Final value of pigs	92.56	72.54	90.87
Returns on labor and investment			
Per lot	-10.23	-26.30	-14.70
Per pig	-0.93	-2.38	-1.34

Prices:

Red clover pasture, second crop, $15 per acre.
Sweet clover pasture, first year's growth, $11.25 per acre.
Rape pasture, $18.50 per acre.
Barley, $3 per 100 pounds.
Cost of pigs when put in pasture, $20 per 100 pounds.
Value of pigs at end of pasture season, $13 per 100 pounds.

the end of the pasture season than was charged at the beginning of the test. Thirteen dollars per 100 pounds for pigs weighing 50 to 65 pounds is rather low, but for the sake of uniformity throughout the bulletin this price is used. Red clover pasture proved to be most valuable and rape ran second in value for this purpose.

EXPERIMENT CONDUCTED IN 1918

In tables XXVI, XXVII, and XXVIII are given data comparing red clover pasture and blue-grass and white clover pasture for swine. The mixed pasture apparently consisted of about equal parts of forage from the two plants.

The pasture requirements as well as the barley required per pound of gain were greater on the mixed pasture. Table XXVIII shows that the cost of gains was greater and the returns over cost of feed and pasture less for the lot on mixed pasture.

According to the results of this preliminary test, mixed blue-grass and white clover pasture is not as valuable for pork production as red clover pasture. In the absence of clover or alfalfa pasture, however, this mixed pasture can be used to advantage for growing young pigs. The white clover was pastured off much more closely than the blue-grass. It was very slow in starting the following year, apparently being set back seriously by the close grazing.

TABLE XXVI—RED CLOVER AND MIXED PASTURE

Pasture period

		Lot I	Lot II
		Red clover pasture	Blue-grass and white clover pasture
Barley fed daily		1 lb. per head	1 lb. per head
Length of pasture period (days)		90	90
Number of pigs in lot		10	10
Acreage of pasture required			
Before first cutting		0.25	
After first cutting		.75	
Average or total		.50	0.75
Average number of pigs per acre		20	13
Initial weight of lot	(lbs.)	479	472
Initial weight per head	"	48	47
Final weight of lot	"	866	811
Final weight per head	"	87	81
Total gain of lot	"	387	339
Average daily gain per head	"	0.43	0.38
Total barley eaten	"	900	900
Average daily ration of barley per head	"	1	1
Barley eaten per pound gain	"	2.33	2 65

TABLE XXVII—RED CLOVER AND MIXED PASTURE

Summary

		Lot I	Lot II
		Red clover pasture	Blue-grass and white clover pasture
Barley fed daily during pasture period		1 lb. per head	1 lb. per head
Length of experiment (days)		150	153
Number of pigs in lot		10	10
Acreage of pasture required		0.50	0.75
Average number of pigs per acre		20	13
Initial weight of lot	(lbs.)	479	472
Initial weight per head	"	48	47
Final weight per head	"	1997	2034
Final weight per head	"	200	203
Total gain of lot	"	1518	1562
Average daily gain per head	"	1.01	1.02
Total feed eaten			
Barley	"	4610.70	5131.10
Tankage	"	247.30	288.90
Total	"	4858	5420
Feed eaten per pound gain			
Barley	"	3.04	3.29
Tankage	"	.16	.18
Total	"	3.20	3.47

TABLE XXVIII—RED CLOVER AND MIXED PASTURE

Financial statement

	Lot I	Lot II
	Red clover pastre	blue-grass and white clover pasture
Barley fed daily during pasture period	1 lb. per head	1 lb. per head
Number of pigs in lot	10	10
Cost of 100 lbs. gain	$10.33	$11.13
Initial cost of pigs	95.80	94.40
Cost of pasture required	10.00	11.25
Value of barley eaten	138.32	153.93
Value of tankage eaten	8.42	8.67
Total of pigs, pasture, and feed	252.54	268.25
Selling value of finished hogs	279.58	284.76
Returns on labor and investment		
Per lot	27.04	16.51
Per pig	2.70	1.65

Prices:

Barley, $3 per 100 pounds.
Tankage, $3 per 100 pounds.
Clover pasture, $20 per acre.
Blue-grass and white clover pasture, $15 per acre.
Initial cost of pigs, $20 per 100 pounds.
Selling value of finished hogs, $14 per 100 pounds.

CONCLUSIONS

1.—Increasing the amount of barley fed to pigs during the pasture period—

(a) Increases the daily gain.

(b) Increases the amount of barley required to produce a pound of gain.

(c) Decreases the amount of pasture required.

(d) Decreases the time required to grow the pigs to suitable weight and condition for market.

(e) Decreases to some extent the profit of the operation, when fed according to the method employed in these tests.

2.—Carrying weanling pigs of an initial weight less than 35 or 40 pounds on red clover pasture only does not appear to be a good practice. The gains under these conditions are very small and, unless they are especially thrifty, there is much danger that pigs will die or become permanently stunted from underfeeding. The amount of concentrates required for gains by pigs fed no grain during the pasture period is not appreciably less than is required by pigs receiving a light grain ration during the pasture period.

3.—Rations of 2 pounds or less of barley per 100 pounds live weight daily in addition to pasture are not sufficient to maintain a very satisfactory condition of young pigs for purposes of exhibition. Such methods of feeding would not be recommended, therefore, for the breeder of pure-bred swine as the better appearance of the pigs fed a heavier ration would be of sufficient value to more than cover any additional cost.

4.—By the use of suitable pasture crops the grain ration can be made very small, thus enabling the grower to carry a considerable number of swine through the summer season on a small supply of grain. The hogs can then be finished on the new grain crop.

5.—Feeding 1 pound of barley per head daily during the pasture period gave very good results in a preliminary test. This method has an advantage in supplying liberal amounts of feed while the pig is small. It is also simple and convenient.

It should be noted in connection with the foregoing results that a supplement—tankage—was fed along with the grain during the finishing period. Without a supplement, no doubt different results would have been obtained. As a result of preliminary tests at this

station it seems that the heavier rations of barley during the pasture period would have shown better comparative results if no supplement had been used during the finishing period.

6.—While the tests of clover and alfalfa pastures were not conducted during the same years, the similarity of methods followed in the two cases and the rather marked difference in the results warrant the statement that alfalfa pasture appears to be more satisfctory for pigs than clover pasture.

7.—In a preliminary test, mixed blue-grass and white clover did not prove as valuable as red clover.

8.—Of the annual forage or pasture crops, rape proved much more effective than barley or oats or a mixture of oats and rape. The grain crops did not prove very satisfactory as pasture crops for pigs.

9.—Red clover proved somewhat more effective than rape as a pig pasture in parallel tests.

10.—Sweet clover in a preliminary test did not prove highly successful as a pasture crop for pigs. The palatability of this crop seemed rather inferior and its growth late in the season was rather slow.

The following illustrations were made from photographs of pigs used in the experiment conducted in 1916, comparing different methods of feeding pigs on clover pasture. Figures 1 to 5 represent the pigs after they had been on pasture and on their resepctive rations for about one hundred days. Figures 6 and 7 represent lots III and V when finished for market. At the close of the pasture season all lots were put in small pens and self-fed on a mixture of barley 92 per cent and tankage (Montana brand) 8 per cent.

FIG. 1.—Lot I was fed 1 pound of ground hull-less barley per 100 pounds live weight daily while on medium red clover pasture. Photograph taken after grazing 100 days.

FIG. 2.—Lot II was fed 2 pounds of ground hull-less barley per 100 pounds live weight daily while on medium red clover pasture. Photograph taken after grazing 100 days.

FIG. 3.—Lot III was fed 3 pounds of ground hull-less barley per 100 pounds live weight daily while on medium-red clover pasture. Photograph taken after grazing 100 days.

FIG. 4.—Lot IV was self-fed on ground hull-less barley while on medium red clover pasture. Photograph taken after grazing 100 days.

FIG. 5.—Lot V was fed no grain while on medium red clover pasture. Photograph was taken after grazing 100 days. But seven of the nine pigs which made up this lot at the beginning survived the treatment.

FIG. 6.—Lot III when finished for market. After the pasture season closed they were self-fed on a mixture of ground hull-less barley 92 per cent and tankage 8 per cent.

FIG. 7.—Lot V when finished for market. After the pasture period these pigs were fattened on ground hull-less barley supplemented with tankage. It is evident that pigs can be grown to satisfactory market hogs after being carried along in thin condition if not too seriously underfed. It should be noted, however, that a first-class supplement was used during the finishing period.

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Farm Practice in Growing Sugar Beets in the Billings Region of Montana

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UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ November 15, 1918

FARM PRACTICE IN GROWING SUGAR BEETS IN THE BILLINGS REGION OF MONTANA.[1]

By S. B. NUCKOLS, *Assistant Agriculturist, Office of Sugar-Plant Investigations,* and E. L. CURRIER, *Professor of Farm Management, Montana Agricultural College.*

CONTENTS.

BASIS OF THE STUDY.

To obtain data on methods of management, labor requirements, and cost of growing sugar-beets, studies were conducted on a large number of farms during the summer of 1916 in the area which grows beets for the beet-sugar factory at Billings, Mont., including farms

[1] This bulletin was prepared jointly by the Montana Agricultural Experiment Station and the Bureau of Plant Industry and with the approval of the Office of Farm Management. The blanks used in collecting these data were prepared in the Office of Farm Management, hence the material incorporated in this bulletin is identical in form with that in the other bulletins of this series prepared jointly by the Office of Farm Management and the Bureau of Plant Industry. The members of the staff of the Office of Farm Management were engaged in taking records in other localities at the time this work was done, and for that reason they are not represented in connection with the preparation of this bulletin.

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in the irrigated areas of Yellowstone, Stillwater, and Carbon Counties. Usable data were taken on 305 farms representing a sugar-beet crop of 8,849 acres, being about 36 per cent of the entire acreage grown for this factory during the year 1915. This acreage is generally distributed throughout the entire area and is believed to be typical of the region at the time the survey was made. The costs here given may not be accurate for present conditions. There have been, however, no changes in the methods of handling the crop tending to reduce the labor necessary to produce it; therefore, by readjustment to allow for prevailing labor prices these data can be applied to the present cost of production.

Records were taken on all types of farms of the area except such as seemed not typical of the region. A labor-income farm survey had been made of this region in 1915 by the same men who had charge of this survey. As the leases are for only one year and the owners often do not live in the region, data on many of the tenanted farms are hard to get, but records were obtained on 133 tenant farms, of which 77 were farms upon which the tenant had farmed but one year. After eliminating records of doubtful value, 305 records remain, on which the statements of this bulletin are based.

PROCEDURE.

The data presented in this bulletin, though not taken from systematic records kept on the farms, are based upon a large number of estimates given by beet growers. The results represent the best judgment and experience of men who have been actively engaged in the production of this crop. The schedules were filled out by well-trained enumerators and not only afforded complete information pertaining to farm practice and farm costs in the production of sugar beets but also furnished data showing the outcome of the entire business of the farm for the particular crop year to which they applied.

DESCRIPTION OF THE REGION STUDIED.

The portion of the Yellowstone Valley covered by this survey (fig. 1) consists of two parts, viz, the Huntley Irrigation Project and the irrigated area extending from Billings as far west as the town of Park City.

HUNTLEY IRRIGATION PROJECT.

The Huntley Irrigation Project occupies a strip of land along the south side of the Yellowstone River, from Huntley, Mont., eastward to Pompeys Pillar, a distance of about 22 miles. This strip of land has an average width of 3½ to 4 miles and comprises an area of 32,405 acres. This land was originally divided by the Government into

tracts containing 40 to 80 acres, but at present many of the units have been combined so as to form larger farm areas. The soils of this area contain a rather high percentage of clay and are inclined to be heavy and somewhat difficult to till.

For several years the lower portion of the project has suffered rather badly from the effects of seepage water and a consequent accumulation of alkali salts on the surface of the soil. An extensive drainage system is being installed, which will probably do a great deal toward relieving this condition.

The growing of sugar beets forms the basis for the agriculture of this region. Other important crops are alfalfa, wheat, oats, and barley.

AREA FROM BILLINGS WESTWARD.

The area in the Yellowstone Valley west of Billings comprises a strip of land extending from about 1 mile east of Billings to 1 mile west of Park City, a distance of nearly 25 miles. At Billings this area is about 4 miles wide, and it gradually widens toward the west until at a distance of about 8 miles west of Billings a maximum width of 7 miles is reached. It then narrows abruptly to about 3 miles, which width it approximately maintains to Park City. The area comprises 68,416 acres, or about 107 square miles. The soils of this area for the most part are inclined to be a little heavy, although they seem well adapted to the growth of sugar beets and other crops that are found in this region.

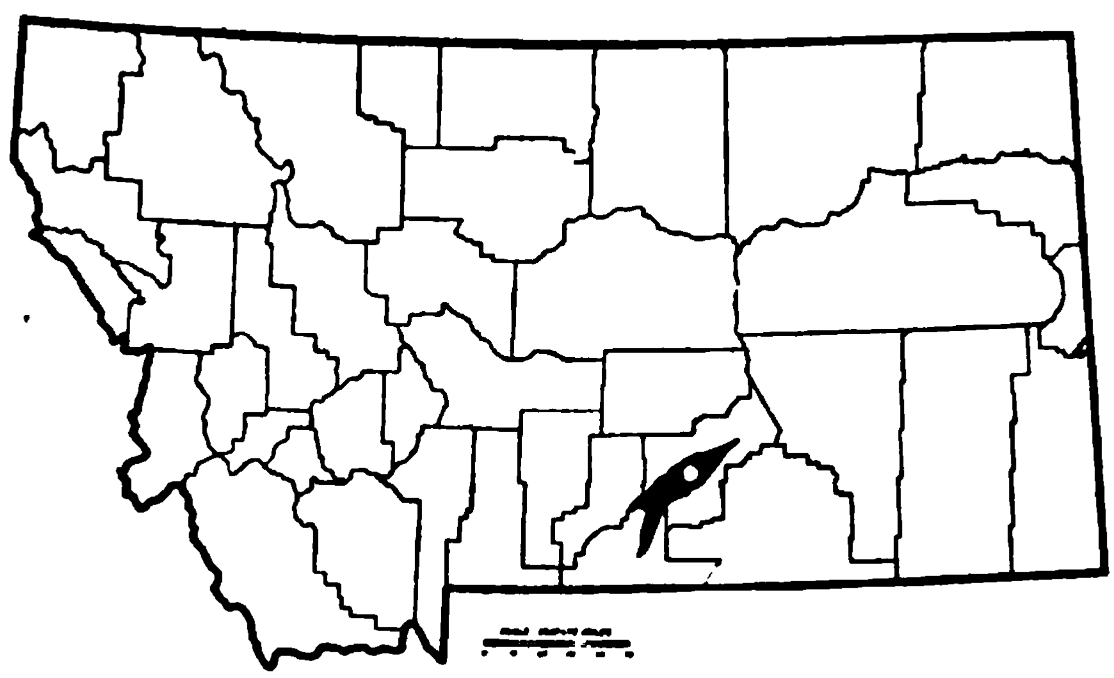

FIG. 1.—Outline map of the State of Montana, showing (in black) the approximate location of the sugar-beet region studied. The white dot in the black area indicates the location of the sugar-beet factory at Billings.

The considerable area of stock range adjoining the area has been an important factor in promoting the agriculture of this valley. On the whole, a well-balanced system of farming has developed, using beets as a cash crop and building around the beet crop a rotation of small grain and alfalfa.

This area as well as the Huntley project is irrigated by waters diverted from the Yellowstone Valley, the supply of which is more than ample for all purposes.

Clarks Fork Valley.—The Clarks Fork Valley occupies a strip of country along the Clarks Fork River about 50 miles long and varying

from 4 to 10 miles in width. The greater part of this area is irrigated from waters diverted from the Clarks Fork River and numerous smaller streams that have their origin in the mountains near by.

Soil conditions in this valley are very similar to those in the adjacent Yellowstone Valley, with the exception that the soils are perhaps a little less heavy and more easy to till.

The altitude of this valley is somewhat higher than that of the Yellowstone, making a shorter growing season and increasing a little the liabilty to frosts. Sugar beets are grown toward the lower end of the valley.

DEVELOPMENT OF THE SUGAR-BEET INDUSTRY IN THE BILLINGS REGION.

The sugar-beet industry has developed rather rapidly in the Billings region of Montana. The factory at Billings has been in operation since 1906. Before that time sugar beets were grown in the region only experimentally, to determine the advisability of establishing a sugar factory. Previous to the introduction of the sugar-beet industry the region was mainly devoted to cattle raising and grain growing. The acreage of irrigated land and consequently the acreage of tillable crops has been increasing in this region for a number of years. Table I illustrates the increase in the acreage of sugar beets grown in this region and gives the average yields per acre for a period of 10 years.

TABLE I.—*Acreage and yields of sugar beets in the Billings region for the 10-year period from 1906 to 1915, inclusive.*

Year.	Total area.	Yield per acre.	Year.	Total area.	Yield per acre.
	Acres.	*Tons.*		*Acres.*	*Tons.*
1906	6,184	9.47	1912	19,017	10.11
1907	8,898	10.75	1913	22,867	10.21
1908	9,457	12.22	1914	18,707	10.91
1909	10,365	10.71	1915	22,233	9.76
1910	10,251	11.76			
1911	15,694	11.56	Average	14,369	10.73

IRRIGATED AREA IN BEETS IN 1915.

Many farms have tillable land that is not irrigated and therefore not suitable for the growing of sugar beets. The computations in Table II are based on the irrigated lands per farm, exclusive of irrigated permanent pastures, as such pastures are often seeped lands or otherwise not suitable for growing sugar beets. Irrigated pasture lands which are in the rotation are included in the tabulation.

The fact that the acreage of beets grown by owners is less than that grown by tenants is not due so much to the size of the farms or to the

character of the lands as to the feeling of responsibility on the part of the owners for the future production from the farms. Landlords and tenants in this territory as a rule are not considering results beyond a 1-year period. Beets being a cash crop, the tenant can pay higher rents where the land is put to beets. Continuous cropping to sugar beets is practiced on tenant farms, and the fact that nearly 4 acres out of each 10 irrigated acres are in beets means that in some cases poor methods of rotation are in use and that ideal conditions exist for the introduction of beet diseases and beet insects. The solution of such problems is in the hands of the landlords and not the tenants, as the leases can be made so that the tenant will grow less beets and be able to practice a rotation of crops. Just what percentage of the irrigated tillable land should be planted to sugar beets is a matter to be decided for the individual farm.

Every farm should have a proper rotation of crops, but the type of soil and the other crops that can be grown have a great deal to do with the percentage of the total area that should be planted in beets. Previous to the introduction of sugar beets into this region there was no common cultivated crop that required summer tillage, the rotations being limited to alfalfa and small grains. Under these conditions many weeds that thrived with such a rotation became established in this region, and much land has been planted in beets in order to kill out these weeds. If continued growing of beets on the same lands is practiced no doubt insects and diseases of the beet will become established, which will necessitate rotation to do away with these pests.

The data collected would indicate that not over 25 per cent of the irrigated tillable area in this region should be planted to beets. This would permit the keeping of some live stock and provide a more substantial and well-balanced system of farming.

Grain and hay farming is not adapted to the needs of the man with a small farm who is trying to get sufficient returns from the farm to make a living for an ordinary-sized family. He must have crops that make a larger gross return per acre and give him a chance to use more labor. Many farms in this region have less than 40 acres of tillable land, and some of these farms have a large percentage of their tillable area planted to beets.

Table II also shows that a smaller percentage of the irrigated land on the larger farms is planted to beets than on the smaller farms. The acreage of beets per farm increases with the size of the irrigated area per farm, but not in proportion. This may be due to the desire on the part of each man to operate his farm with as little hired labor as possible; that is, there is a tendency toward the 1-man farm. On some of the smaller farms the operator has to grow intensive crops in order to occupy his entire time.

TABLE II.—*Classification of the 305 farms studied in the Billings region, according to ownership and size, showing the percentage relation between the total irrigated area and the area planted in sugar beets in 1915.*

Classification of farms.	Number of farms.	Irrigated crops (acres).				Percentage in beets.
		Total planted.		Average per farm.		
		Area.	In beets.	Area.	In beets.	
As to ownership:						
Owners	117	10,276	2,573	87.83	21.99	25.03
Owners renting additional acres	55	5,953	1,622	108.24	29.49	27.24
Tenants	133	12,132	4,654	91.21	34.98	38.36
All farms	305	28,363	8,849	92.99	29.01	31.20
As to size:						
25 acres and less	9	139	107	15.44	11.88	76.97
26 to 50 acres	77	2,844	1,273	36.94	16.53	44.76
51 to 75 acres	67	4,277	1,562	63.83	23.31	36.52
76 to 100 acres	45	3,845	1,357	85.44	30.15	35.29
101 to 125 acres	43	4,893	1,758	113.79	40.88	35.92
126 to 150 acres	28	3,919	1,121	139.96	40.04	28.60
151 to 175 acres	13	2,083	546	160.23	42.00	26.21
176 to 250 acres	14	3,001	653	214.35	46.64	21.75
251 acres and larger	9	3,362	472	373.55	52.44	14.04
All farms	305	28,363	8,849	92.99	29.01	31.20

PREVIOUS CROP.

Of the 8,849 acres of beets included in this survey, it was found that 6,129 acres were planted on land that had been in beets the previous year, 1,640 acres were on land that had been in alfalfa the previous year, 717 acres had been in grain the previous year, 86 acres had been in miscellaneous other crops, and data in regard to the previous crop, covering 277 acres, were wanting. This large acreage of beets planted on land that was in beets the previous year is an indication of a cropping system that should be modified by the growers as soon as possible if they do not wish to have decreasing yields of beets. Beets should not be planted on the same land continuously, even if the farmer has manure to put on the land each year. The figures given would indicate that nearly 70 per cent of the land was planted in beets at least two years in succession. Data for a longer period of time were not obtained, and it is not possible to state how long the average grower devotes land to beets without rotation.

On some farms certain fields are so located with respect to water supply and proximity to the loading dump, and have soil of so favorable a type that they are the most desirable parts of the farm for the growing of sugar beets. Naturally there is a tendency to plant beets on such fields for a number of years. This region having many tenants, no doubt much laxity exists in the planning of the crop rotation.

VALUE OF LABOR.

Throughout this bulletin the value of man labor is computed at 20 cents per hour, or $2 for a 10-hour day. Horse labor is valued at 10 cents per hour, or $1 per 10-hour day, whether the animal is worked single or in a 2-horse, 3-horse, or 4-horse team.

At certain times of the year labor may be rated higher than at other times, but the farmers were not able to give exact figures for different dates. Men were often hired by paying a definite sum per month for the entire year. Consideration was given to the variation in wages, and each grower was asked the highest and the lowest rate he paid for labor by the day or the month during the year. Data were also obtained as to the total time labor was hired and the total wages paid for each farm. Consideration was also given to the value of board furnished the laborers. Taking an average of all replies, it was found that the average wage was as stated above. The value of horse labor was ascertained by similar methods.

The cost of labor varied on different ranches, but in estimating the cost of production of beets for each farm the labor was rated at the average for the region. Family labor or labor done by the grower was figured at the same rate as hired labor.

MANURING PRACTICE.

As has been rather common in most western semiarid regions where the land was broken and planted to grain crops for several years, the farmers of this region have not placed a very high value upon barnyard manure. Manure has had a tendency to stimulate too heavy a growth of straw of the grain crops on these fertile lands. This attitude toward the use of manure soon disappears when the farmers begin to grow sugar beets. The feeding of stock has gradually increased on account of the manure produced, until now many of the sugar-beet growers state that without this by-product little profit would be found in the growing of sugar beets. The beet crop produces a great deal of stock feed in the form of tops, pulp, and waste molasses. Alfalfa hay grows well in this region, and this, with the grazing on range lands and the feed from the beets, furnishes the basis of an increasing feeding industry. It was reported that 36.7 per cent of the land planted to beets in the surveyed area had been manured at some time during the past three years. It was assumed that the manure would give beneficial results to crops for that length of time at least. The value of manures and the length of time over which the cost of application should be distributed were reported upon by all farmers, leaving little doubt as to the general sentiment in regard to the value of barnyard manures in the produc-

tion of a crop. The rainfall in this region is not heavy, and manures do not rot and become available plant food as rapidly as they do in more humid regions. In averaging the result of the numerous answers upon this point it was decided that the nearest correct method of distributing the cost of manuring was to charge 40 per cent to the first crop, 40 per cent to the second crop, and 20 per cent to the crop grown the third year after the manure was applied. Some men favored a longer period of distribution. That the manure on land was worth as much to the second crop as it was to the first was the almost unanimous opinion. As many farmers stated that the second year was better than the first as the reverse, the usual answer being that the two crops were equally helped. Considering this, the distribution stated above as to cost of manure and manuring seems to be justified. That is, on the land where beets were grown but one year after manuring, the charge would be 40 per cent of the value of the manure in the yard and 40 per cent of the cost of the labor of spreading the same. If the land had been manured for two years in succession before planting the beets, the charge would be 80 per cent of the yard value plus 80 per cent of the cost of application. If land had been manured for the three years previous to the growing of the 1915 crop of beets the charge would be 100 per cent of the cost of the manure and all the labor charges. The cost of manure and manuring was charged to every farm in this manner. Commercial fertilizers were not used, and the growing of special green-manure crops is almost unknown; however, a form of green-crop manuring exists. It is common to plow under alfalfa that has some green growth when being plowed. Most men who practiced this considered a green crop of alfalfa as beneficial as a 15-ton per acre coat of barnyard manure. Of the 1,640 acres of alfalfa broken and planted to sugar beets in 1915, a large part of it had some green growth at the time of plowing.

The value placed upon manures and the fact that commercial fertilizers are not used is easily explained when the character of the soil is taken into consideration. This is a soil that runs rather low in humus but relatively high in mineral nutrients.

Sugar-beet growers almost without exception used their total available manure upon the land to be planted immediately to beets. This might in part be due to the fact that no other cultivated crop is grown to any great extent by most of these men, but their opinion was that the manure was most readily available and most beneficial when applied to beets.

The methods of applying the manure varied, but most of the growers used wagons and forks. Only 98 growers used manure spreaders, while 207 used farm wagons. The manure is mostly

spread in the winter and early spring, and most men prefer to get manuring done when they have spare time. If the manure can be plowed under soon after it is spread, the spreader is the most successful method, but where manure is hauled to the field a long time before it is to be plowed under it is best to place it in small piles and spread it with a fork just before plowing. Spreading and disking under is often a better method than to pile the manure.

Either piling or disking the manure may cause a little more labor, but this method permits the work to be done at a time when teams are not busy, thus conserving the value of the manure by preventing its drying out and blowing away. To spread manure on the fields, leaving it exposed in this dry climate, entails a loss from the heavy winds that sometimes come in the early spring. That most farmers do their own work of spreading manure is indicated by the fact that on 62 per cent of the farms where manure was applied the spreading crew was one man and two horses and 69 per cent of the farmers used a 1-man crew.

It cost 27 cents per ton to distribute manure with one man to a wagon or spreader and a team of two or more horses; with two men to an outfit it cost 23 cents per ton, and with three men 20 cents. This variation in cost is due to at least two factors: (1) The larger crews were spreading a greater acreage, and (2) in most cases they used manure spreaders and did their work at a more rushed season. The man with little manure to spread does not usually use a spreader, and the man who uses a spreader prefers to spread the manure at a time when it can be plowed or disked under immediately.

One man with a 2-horse team did double the work per horse that was done by one man with a 4-horse team, the same being true of three men with 3-horse teams as compared with three men using 6-horse teams. This is perhaps due to the number of horses that stand idle while the manure is being loaded. A crew consisting of three men and six horses used two spreaders with a 3-horse team on each spreader. While two men and one 3-horse team were engaged in loading, the other man with his 3-horse team was spreading the manure. With three men, a 3-horse team, and two spreaders, two men loaded the spreaders and one man with the three horses spread the manure, switching the team from one spreader to the other. This appeared to be a very quick and efficient method, as one spreader was being loaded while the other was being unloaded.

A total of 49,570 tons of manure was spread on sugar-beet land in this region for the 1915 sugar-beet crop. At the estimated yard value of 85 cents per ton this would be worth $42,298, but according to the method of distributing the charge to the immediate crop after manure has been applied it was found that 79 per cent of this sum,

or $33,510, should be charged to the 1915 crop of sugar beets. It thus appears that the total charge against future crops is greater than the amount that is accumulated in the soil from previous years. If the entire amount of manure used had been spread upon all the sugar-beet land devoted to the 1915 crop, the average per acre would have been 5.6 tons; but some growers spread as high as 25 tons per acre, and the average of 15.3 tons was spread on each acre manured, thus leaving 4,599 acres of land with no manure to benefit the 1915 crop of beets.

The growers on 72 farms did not manure any of the land they put in beets, 62 growers manured less than 25 per cent of their beet area, 116 used manure for approximately 50 per cent of their beet area, and 55 manured 75 per cent or more of all the land they put in beets. The lands that were manured as a whole produced a good increase in the yield, and, after deducting the value of the manure at 85 cents per ton and the cost of the labor of spreading it, a net profit of $1.41 per acre, due to manuring, is shown for the entire area. (Table III.)

TABLE III.—*Use of manure as affecting yields of sugar beets in the Billings region.*

[The valuation of beets is that given by the growers.]

Classification.	Not manured.	Percentage of area devoted to beets upon which manure was used.			All farms.
		1 to 24½.	25 to 74½.	75 to 100.	
Area devoted to beets.....acres..	1,908	2,055	3,443	1,443	8,849
Beets produced.....tons..	18,835	20,328	38,183	17,855	95,201
Production per acre.....do....	9.87	9.89	11.09	12.37	10.76
Value of beets sold.....	$110,742	$124,006	$228,022	$107,211	$569,981
Value of beets per acre.....	58.04	60.37	66.24	74.29	64.45
Value of increase of crop per acre.....	....	2.33	8.20	16.25	6.41

In considering the value of the increased yield per acre, the quality of the beets as well as the added tonnage should be considered.

In the comparison of those farms using no manure with those spreading manure on 75 per cent or more of their sugar-beet land, it was found that the estimate of 85 cents per ton for the value of manure in the yard was less than the actual value of the manure, for on this one crop the farmer received an average of $1 per ton for manure by increased crop production after deducting for all labor costs of spreading manure at the usual rates. (Table IV.) This shows that manure has a value, and the beet grower can not afford to let it waste.

TABLE IV.—*Returns to growers using no manure compared with returns to those manuring 75 per cent or more of their sugar-beet area in the Billings region.*

Crop treatment.	Number of farms.	Beet crop.			Returns for manure less the labor cost.
		Area.	Per acre.		
			Yield.	Value of the net increase.	
		Acres.	*Tons.*		
Manured	55	1,444	12.38	$16.10	$12.79
No manure	74	1,908	9.87		

Manure worth $3.79 was put on each acre manured. The cost of its application was $3.31, as it required 8.9 hours of man labor and 15.3 hours of horse labor.

Growers to the number of 233, or 75.7 per cent of the total, manured part of their beet land. They manured 3,250 acres, or 36.7 per cent of the total beet acreage, at some time in the 3-year period prior to the time of planting the 1915 beet crop. As already stated, the writers have assumed that manure is beneficial to the crop for at least three years succeeding its application.

The data showed that in this region the average established owner manured more land than the average tenant, because the tenants were unable to get long leases on the land. The difference in this respect was 17.2 per cent of the area planted to sugar beets. The data also showed that the owners made slightly heavier applications of manure to the land manured. In fact, most of the land manured on tenant holdings was on those farms where the landlord had encouraged the feeding of stock on the land by feeding all the hay which he received for rental. Some landlords were taking an interest in their farms and feeding their hay on the land, and some of the tenants were feeding with the landlord under agreements whereby the landlord advanced the money to finance the buying of feeding stock, and the tenant performed the labor of feeding, thus effecting an exchange of labor for the use of capital.

PLOWING PRACTICE.

The entire area planted to sugar beets was plowed during the preparation of the seed bed. This work was done at an average cost of $2.54 per acre, or an expenditure of 4.59 hours of man labor and 16.18 hours of horse labor. This does not include any labor of crowning alfalfa sod where such lands were crowned before they were plowed.

Almost all the plowing done in this region is done in the spring, as growers do not have time to harvest their beets and do much fall

plowing other than that required for winter wheat. Some crowning of alfalfa is done in the fall and early winter, but little other than alfalfa land is plowed before early spring. Only 23 growers out of a total of 305 did any fall plowing, and only 3 plowed all of their beet land in the fall. Most growers were of the opinion that fall plowing of land for beets was advisable, but generally there was no time for this work because the beet harvest and work on other crops demanded all the available man and horse labor.

The data presented show that the average team of three or four horses and a man will plow a little less than 2 acres of land per 10-hour day.

All the growers plow rather deep in preparing land for sugar beets, and they so plan the operation that the land can be leveled off well for irrigation. The usual depth of plowing is from 8 to 10 inches, some plowing a little shallower or a little deeper, according to the type of soil they have. Two-way plows are used by some, and it was found that they leave the land in better shape for irrigation than plows of other types, as no dead furrows are left in the field. They are not difficult to operate. Definite data as to the number of 2-way plows were not obtained, because in many instances the enumerators did not differentiate between sulky plows and 2-way plows.

The variation in cost for different crews in plowing seems to be more in the cost for man labor than for horse labor. This is due to the fact that with more horses to handle less time is required by the man per horse, while the horse can do about the same amount of labor regardless of the method of hitching. As has been explained in regard to the kind of plows used, the classification of crews might be limited to 2-horse teams, 3 or 4 horse teams, and 5 or 6 horse teams. The 3-horse team seems to have an advantage over the 4-horse team. Part of this may be due to the method of hitching and the facility of turning. A 3-horse team is hitched abreast, while four horses are hitched in two teams tandem in most instances. Most of the advantage is due to the type of soils. In the sections where the soil is more sandy and loose the plowing is almost all done by three horses, and in sections where the soil is heavier all the growers plow with 4-horse teams. The depth of plowing also influences the number of horses required for plowing.

Of the 15 growers who plowed with a crew of one man and two horses, 13 used walking plows, 1 used a sulky, and 1 did not state the kind of plow used. Of the 87 growers who employed 3-horse teams, 8 used walking plows, 77 sulky plows, and 2 gang plows. Of the 110 teams of four horses, 99 were with sulky plows and 11 with gang plows. Of the 17 teams of five horses, 3 were with sulky plows and 14 were with gang plows. Five growers hitched 6-horse teams

to gang plows. The remaining growers did not report the kind of plows used.

In considering the size of plows used, it was found that of the 310 plows reported 122 were 16-inch plows, 170 were 14-inch plows, and 18 were 12-inch plows. (Table V.)

TABLE V.—*Cost of plowing land for sugar beets with different plows in the Billings region in 1915.*

Kind of plow.	Area plowed.	Labor per acre.		
		Cost.	Man.	Horse.
	Acres.		*Hours.*	*Hours.*
Walking	272	$3.33	7.57	18.12
Sulky	6,396	3.10	5.61	19.74
Gang	1,319	1.94	2.85	13.67
Unknown	764	2.71	5.15	16.81
Hired	98	3.45		
All farms	8,849	2.90	5.15	18.32

CROWNING ALFALFA SOD IN PREPARING LAND FOR BEETS.

Alfalfa crowning is done in the fall or spring when there is some green growth on the alfalfa plants, which when plowed under adds to the humus content of the soil.

A total area of 1,394 acres of alfalfa land was crowned for beet growing by 69 farmers. This labor takes about as much time as to plow the land. It requires 4.35 hours of man labor and 16.14 hours of horse labor to crown 1 acre, and the cost is figured at $2.48 per acre. If the work can not be done in the fall it is done as soon as possible in the spring, if the land is for beets that year. The plowing is to a depth of 3 or 4 inches, which is sufficient to cut off and turn over most of the alfalfa plants. The ground is then harrowed. The exposed alfalfa roots and crowns soon dry out and die, while if plowed to a greater depth many of them would sprout up again. After allowing the roots to dry out for a few weeks the land is plowed again to a greater depth, with the result that few of the crowns then turned under grow again. This method of handling alfalfa sod is much better than plowing only once, as it makes a better seed bed and does away with much volunteer alfalfa, which would make beet cultivation very difficult; also not so many roots are left on top of the ground to clog the cultivating machinery. The cost of the extra work of crowning is easily saved in the later work of thinning and cultivating the beet crop. Most of the growers prefer to crown in the fall if other work permits, so as to let the crowns dry out over winter before turning them under; in actual practice, however, few of them were able to do much alfalfa crowning in the fall. Of the total of 1,640 acres of alfalfa broken and planted in beets, 1,394 acres were

double plowed (or crowned and plowed) and 246 acres were plowed but once. Of the 1,394 acres crowned and plowed, 309 acres were crowned in the fall and 1,085 acres crowned in the spring. More of this crowning would have been done in the fall if the farmer could have found time to do it at that season of the year.

The crowning of the alfalfa sod is done with the same plows that are used to plow the land, and the time per acre for various crews runs similar to that required for plowing. The explanation of the variation in costs of plowing under varying conditions applies also to crowning alfalfa, the reasons being identical.

DISKING PRACTICE.

Disking was not a general practice in this region in 1915, as is shown by the fact that only 26.9 per cent of the farmers disked any land, and only about 21 per cent of the total area was disked. The plowing table shows that most of the land was plowed. Where disking was done, it was mostly by men who were preparing alfalfa land for beets. Some growers disked manured land before plowing.

Of the 82 growers who used the disk in preparing beet land, it was found that 7 used 12-disk implements, 40 used the 14-disk size, and 28 used 16-disk machines. The remaining 7 made no report as to the size of disk used.

Averaging all the farms, it is found that one man with the average number of horses (about four) can double disk 5.4 acres in a 10-hour day. A small number of farms use other than 4-horse teams for disking, so that a comparison of the cost by crews does not indicate much of practical value. The average acre disked required 1.84 hours of man labor and 7.19 hours of horse labor. This was applied at an average cost of $1.09 per acre for the 1,874 acres disked on 82 farms.

FLOATING PRACTICE.

The implement used in the operation of floating land is usually a homemade piece of machinery made from sawed timbers 2 or 3 inches thick and 12 inches wide; the length varies from 12 to 24 feet and the width from 6 to 14 feet. (Fig. 2.) Of the total number reporting, 50 per cent reported 16 feet as the length of the float, and most of those remaining were more than 16 feet in length. As to width, 20 used 6-foot floats, 12 used 7-foot widths, 89 used 8-foot widths, 33 used 10-foot widths, and 14 used floats wider than 10 feet. The pieces are bolted together so that the planks have only one edge touching the ground when in use. The three crosspieces usually provided serve to drag down the higher places in the field and deposit dirt in the depressions. This is an excellent implement for getting ground in level condition, so as to irrigate well. The longer floats

do good work in leveling where depressions are wide. A narrow implement will have a tendency to scoop out these places. Four or more horses are needed to handle a large float properly, the average number for the region being a little more than four. The number of horses needed and the efficiency of operation depend upon the size and weight of the float. Some lighter material is commonly used on top of the implement in order that the driver may ride standing or move about, so as to make the leveling more nearly perfect.

Practically all the growers in the region used some such machine, a total of 8,580 acres (nearly 97 per cent of the area planted to beets) being thus prepared.

The growers who did not use a box level of this sort used a drag made of overlapping planks. These drags are usually from 3 to 5

FIG. 2.—Floating sugar-beet land. The homemade implement here shown is used after disking to level the ground and put it into good condition for irrigation.

feet wide and 8 or 10 feet long. The drag is not considered so efficient an implement for leveling land as a level; the work it does is not so thorough. The drag is a somewhat less expensive implement to make and to operate and it requires less horsepower. The average cost for the 325 acres dragged was 66 cents per acre.

The average acre of land included under the survey was floated 1.82 times at an average cost of 89 cents per acre. This is the equivalent of 1.51 hours of man labor and 5.96 hours of horse labor. One man with a 4-horse team can float about 12 acres per day. The average cost is 49 cents per acre, or 0.83 hour of man labor and 3.27 hours of horse labor, to go over an acre once with a float.

Of the farmers who floated their land, 70 per cent went over it twice, 22 per cent floated only once, and the other 8 per cent floated more than twice. In floating twice it is the common custom to float both ways of the field.

Of the 302 growers who floated their land, 205 used 4-horse teams. The cost of floating with crews of different sizes can not be used for any practical application, for the men using the greater number of horses invariably have the heavier floats. These heavier floats usually accomplish more in the way of smoothing and firming the seed bed than the lighter floats for an equal number of operations.

HARROWING PRACTICE.

It required an average of 1.75 hours of man labor and 5.75 hours of horse labor to harrow an acre. All of the farmers harrowed their land in preparing the seed bed for beets; 246 growers used 2-section harrows, and 49 used 3-section harrows, while 13 used harrows of unclassified types. (Fig. 3.)

FIG. 3.—A 4-horse team harrowing a field of sugar beets. This crew economizes man labor.

Of the total number of growers, 31 harrowed their land but once, 158 harrowed twice, 70 harrowed 3 times, 34 harrowed 4 times, 4 harrowed 5 times, 4 harrowed 6 times, 2 harrowed 7 times, and 1 harrowed 10 times. The average field was harrowed 2.44 times, at an average cost of 38 cents per acre, or a total cost of 93 cents per acre.

Harrowing varied a great deal on the various farms, owing to two causes. The type of soil has a great deal to do with the number of harrowings that are necessary, and in this region the growers who use disks, drags, and levels do not use the harrow so much as those who have less machinery of this sort and who use the harrow as a sort of float or level by turning the teeth horizontal to the surface of the ground. The first harrowing of the land is usually done immediately after plowing. A man will harrow once what is plowed

each day, so as to prevent rapid drying out and the formation of hard clods. As a rule, this is done by the same man who does the plowing by switching from the plow and using the harrow for a time each day. A few men attach small narrow harrows to their plows. The practice of harrowing the land as soon as it is plowed is an efficient one, as much good can be accomplished with the harrow at that time.

Spring-tooth harrows are not used to any great extent in this region, as is shown by the fact that only 103 acres of land were harrowed with these implements. Most men who use a spring-tooth harrow use it in place of a disk. One man with a 4-horse team was the crew mostly used in spring-tooth harrowing, and the cost per acre to do this work averages $1.05 per acre harrowed, or 5.7 acres per 10-hour day for a crew of one man and four horses.

ROLLING PRACTICE.

The practice of rolling land before planting the beet seed is not general in this region, as is shown by the fact that only 27.8 per cent of the 305 farmers visited reported rolling land before planting, and less than 21 per cent of the total area planted to beets was rolled before planting. This might vary somewhat with different seasons, as rolling to firm the land for a good seed bed would be necessary in some years and not in others; however, in this region there is seldom much trouble with lack of firmness in seed beds for beets. Rolling is usually done to break clods.

The average 10-hour day's work at rolling by one man with a 2-horse team covers almost 14 acres of land; hence to roll 1 acre of land requires an average of 0.71 hour of man labor and 1.49 hours of horse labor.

Of the 84 men reporting the use of rollers, 50 used 10-foot rollers, 25 used 8-foot rollers, 6 used 12-foot rollers, and 3 used rollers less than 8 feet long. Data were not obtained as to the number of smooth and of corrugated rollers.

Of the 84 men using rollers, 80 hitched two horses to the roller; and the average man rolled his land 1.13 times, at a cost of 29 cents per acre.

DITCHING PRACTICE.

The cost of maintaining the small laterals, including the work of cleaning them out and the making of such new small ditches as may be necessary for the distribution of the water in the field so that it can be run into the furrows between the rows of beets, is only 13 cents per acre. This required 0.32 hour of man labor and 0.61 hour of

horse labor. The factors that affect the cost are the distance from the main lateral or ditch, the size of the fields, and the lay of the land. Some teamwork is used in plowing out ditches, but they must be cleaned out with shovels. A total of 8,666 acres was considered in the above as having a separate cost for ditch cleaning, six farms being so located that no extra work was required to get water to the beet field. This is a part of the cost of irrigation. Very few growers had any special tools for ditching, and they used common walking plows for plowing out ditches. A few had listers; others used homemade V drags.

In taking the records no separate accounting of the man labor and the horse labor was made, so no estimate can be given as to the hand labor done with shovels in cleaning out the ditches.

As already stated, the ditch cleaning is very variable, according to the type of ditches necessary to get water to each farm, and no comparison can be made as to the efficiency of the methods used by the individual farmers. Some seem to use more efficient tools than others, but as a general rule this work is governed by the lay of the land. More work is necessary in some years than in others, and a part of this work is sometimes more in the nature of a permanent improvement.

PLANTING BEET SEED.

Of the total of 305 growers in this region all but 3 used drills drawn by two horses each that planted four rows at a time. The other drills planted only two rows at a time. With a 4-row drill, the average area planted per 10-hour day was a little over 10 acres. Planting in this region begins as early as possible in the spring, sometimes the early part of April, and lasts until about the first of June. Early-planted beets seem to do better than those planted later, but the time necessary to prepare the land does not always permit early planting. Where the field is very large it is the custom to plant at different times, so that the thinning will be distributed over a longer period. It is not advisable to let the beets stand too long before thinning.

The most of the acreage in this area is planted in rows 20 inches apart. A few men planted rows 18 and 22 inches apart, so that it was possible to make a deeper irrigation ditch between the wide rows and irrigate only between alternate pairs of rows. This custom is not very common in this region, as the soil is heavy and water does not quickly soak across the rows where the furrows are very far apart. Also the land in most instances has a good slope for irrigation, and there is no need of a deep furrow or large head of water for irrigating between the rows of sugar beets.

It cost 40 cents per acre to plant beet seed, or one hour of man labor and two hours of horse labor.

ROLLING LAND AFTER BEETS ARE PLANTED.

After being planted, 4,935 acres, or 56 per cent of the total area in beets, was rolled. This rolling is usually done after the beets have come through the ground and before they have grown very much. It cost 31 cents to roll an acre of beets, or 0.77 of an hour of man labor and 1.55 hours of horse labor. Rolling is done for two purposes: (1) To break any crust that may have formed on the ground and enable many beets to come up that would not otherwise be able to get through, and (2) to break and crush clods that would be likely to be thrown on the beet row at the first cultivation. Most growers use corrugated rollers run crosswise of the beet rows. (Fig. 4.) Very few use smooth rollers, as they are not as efficient for breaking

FIG. 4.—A corrugated roller used on beet land. A good type of roller for firming the seed bed.

a crust on the land. Some growers rolled the beets after they were blocked and thinned, so as to firm down and level the soil and aid in cultivating.

By far the greater number of growers use only two horses in rolling beets. One man with two horses can roll an average of 13 acres of land per 10-hour day.

After the seed was planted, 178 of the men rolled a part of their beet land, and only 27 of these rolled the land more than once.

More rolling is done in some years than in others, because there is much variation in the seasons; for example, should a heavy rain occur between the time of planting the beet seeds and their germina-

tion, a heavy crust is likely to form on the ground and the small plants are unable to break through, which necessitates rolling to break the crust. If the ground is cloddy, the rolling should be done before the seed is planted, as beets never give the best results where there is lack of care in the preparation of the seed bed. Getting the young plants well started early in the spring is one of the essentials of a good tonnage of sugar beets. Rolling does not seem to damage the plants to any great extent, as they do not break off easily and the small leaves are not often crushed.

FIG. 5.—Cultivating sugar beets with a 4-row cultivator, which will do twice as much work as a 2-row machine, with practically the same amount of man labor and horse labor.

CULTIVATION OF BEETS.

Cultivation starts as soon as the beets are well through the ground and continues during the season at short intervals until the beets are so large that they shade most of the ground and one can not get through the rows without breaking the leaves. In early cultivations the work must be done slowly and carefully, as the beets are very small and there is danger of covering them with dirt. Knives or duck feet are used for the first cultivation, or both are used by attaching the duck feet behind the knives. (Fig. 5.) In later cultivations larger shovels are used, and the work can be done more rapidly than in the earlier cultivations. In the first cultivations the ground should

be loosened to a good depth. If possible, shovels should be run in the middle between the rows, for if this strip of ground is allowed to get hard satisfactory cultivation will be difficult. Early deep cultivations, if not too close, do not disturb any of the beet roots, while late, deep cultivations are apt to injure the beet roots. As much care should be taken to avoid injury to the roots of the beet as to the tops, for both roots and tops are essential to the growth of the plants. The first root of a beet strikes down deep into the soil and the side roots spread out later.

The cultivation of beets is in most instances done by 2-horse cultivators, which till four rows at a time; 37 growers used 1-horse cultivators that worked only two rows at a time. These 2-row cultivators are not as efficient as the 4-row implements, as they take about twice the man labor per acre, and the horse labor is about the same as for the 4-row machine. It takes two hours for a man to cultivate 1 acre with a 2-row cultivator and only one hour with a 4-row implement. Cultivators of the 2-row type are not used on large areas, as is shown by the average acreage of beets of those using 1-horse cultivators being only 14.5 acres per farm, while the average for those using 2-horse cultivators is 31 acres per farm. (Table VI.)

TABLE VI.—*Relation of the number of cultivations of the sugar-beet crop to the cost of labor in the Billings region in 1915.*

Cultivated.	Number of farms.	Acres of beets.	Percentage of total area.	Average labor cost per acre.[1]	Cultivated.	Number of farms.	Acres of beets.	Percentage of total area.	Average labor cost per acre.[1]
2 times...	12	372	4.2	$0.79	6 times...	13	614	6.9	$2.23
3 times...	86	1,964	22.2	1.28	7 times...	9	288	3.3	2.81
4 times...	125	4,183	47.3	1.68					
5 times...	60	1,422	16.1	2.20	All farms.	305	8,843	100.0	1.74

[1] The cost of the labor for furrowing, which is usually done once each season and by some is considered a cultivation, is not here included.

There is no clear indication that the number of cultivations had any great effect on the yield of beets per acre, there being many factors that might tend to cause a variation in yield; for example, the ground in certain fields may be in poor condition or the beets may not be doing well, and such a field will receive extra cultivations, while a good field may not be cultivated so often. Weedy land will be cultivated more often than fields that are comparatively free from weeds. Beets that are growing rapidly and are healthy and vigorous have a shorter season for cultivation before they become too large, but such beets usually yield best.

It required 4.46 hours of man labor and 8.46 hours of horse labor to cultivate an acre of beets an average of 4.09 times. (Table VII.)

TABLE VII.—*Relation of crew labor to the cost of cultivating the sugar-beet crop in the Billings region in 1915.*

Crew.	Number of farms.	Acres of beets.	Average times cultivated.	Cost of cultivating per acre.	
				Once over.	Total.
1 man, 1 horse	37	537	3.63	$0.60	$2.19
1 man, 2 horses	265	8,206	4.19	.41	1.71
Hired	3	98	3.41	.50	1.70
All farms	305	8,841	4.41	.42	1.74

FURROWING FOR IRRIGATION.

To furrow the average acre requires one hour of man labor, and the team or horse labor is nearly two hours, being a little less than double the amount of man labor because some men use only one horse for furrowing. The average cost of labor for furrowing is 39 cents per acre. Only seven growers furrowed twice, and only one did not furrow, the others furrowing once.

The ordinary beet cultivator is used for furrowing, shovels that make small ditches about 3 or 4 inches deep being attached.

Implements covering two rows were used by 35 growers; 12 furrowed five rows at a time, one man did not furrow, and the remainder four rows at a time. The furrower makes one extra ditch each time across, but doubles back in it in cases where two or four rows are furrowed at a time. Those growers who used 2-row furrowers did not have very large acreages of beets, averaging only 6 acres per man. Their acreage being small, it probably would not pay them to buy more expensive machinery. They furrowed on an average 5.77 acres per 10-hour day at a cost of 52 cents per acre, this being 13 cents per acre more than the average cost for the entire area.

In furrowing four rows at a time the average day's work of a man and 2-horse team for a 10-hour day was 10.72 acres, at a cost of 37 cents per acre.

In furrowing five rows at a time the man and 2-horse team averaged 12.71 acres per 10-hour day, at a cost of 31 cents per acre. Although this is the least in cost per acre for furrowing, it is very doubtful whether it is the most economical method. It is necessary that more care be taken to cover all the rows in the same order, as they are planted by a 4-row drill. If the rows are a little wide or close between drill rounds, this method will plow up some beets; and 6 cents per acre is a small saving, as a few beets will more than amount to this sum. A dozen beets plowed out or covered per acre would eliminate any saving, regardless of other losses.

IRRIGATING THE SUGAR-BEET CROP.

Irrigation in the Billings region is by water supplied directly from the river to the farms and not stored in reservoirs, such as are found in many sections elsewhere. The supply is from the Yellowstone River and its tributaries, and much of the water is available in June and early July, as this is the time when the water in the river from the melting snows of the mountains at the headwaters of the Yellowstone River reaches its highest point. Large ditches are constructed to take the water from the river, and these ditches run at an altitude higher than the lands to be irrigated. By a gradual branching into smaller ditches the water is distributed to the beet fields, where it is run in small furrows between the beet rows.

In running the water through the furrows between the rows of beets it is necessary to have only a small head, as it is advisable that the water in the furrow should not overflow and submerge the crown of the beets. The furrows are usually about 3 or 4 inches deep. Different types of soil require different lengths of time for the application of the water in order to give the beets a thorough irrigation. Sandy lands require a quick run in order to be most efficient in the use of the water, while heavy soils which the water does not penetrate quickly require a long run of water. The farmer usually judges that the beets have sufficient water when the land is thoroughly saturated to the depth of an irrigating shovel in the middle of the strip between two water furrows. The length of time the water is run in the furrow depends greatly on the length of the row of beets. Many growers shut off the water as soon as it reaches the lower end of the furrow so as to avoid waste of the water from the ends of the rows.

Irrigating usually begins in the month of July, depending on the season, the amount of rains, and the size of the beets. The first irrigation water was applied to beets by 41 farmers of this group from July 5 to 15, 136 began irrigating from July 16 to July 25, 66 began irrigating from July 26 to August 5, and 5 did not apply the first irrigation until after August 6.

Six farmers applied the last irrigation to beets from August 1 to August 5, 14 finished irrigating from August 6 to 15, 83 finished from August 16 to 25, 75 applied the last irrigation from August 26 to September 5, 65 finished irrigating from September 5 to 15, and 5 irrigated beets as late as September 16.

The average length of time between the first and last irrigation of sugar beets was 37 days, while the extreme dates shown for individual irrigations range from July 5 to September 20, which gives a season of 77 days for irrigating.

Beets should not be irrigated until they are too large to cultivate and the leaves have spread out so that they will cover the ground

and shade it (fig. 6), so that the heavy crusts will not form in the furrows where the water has run. The beets are usually ready for irrigation about July 15 to 25. There is a popular belief that early irrigation tends to shorten the root of the beet, but this is not true where the beet is suffering for want of water. If the season is dry the farmer should not wait too long to irrigate. A beet should be kept in the best growing condition possible at all times and should not be allowed to lie dormant or have its growth checked when an application of irrigation water would make it grow rapidly. The

FIG. 6.—A flourishing field of sugar beets. When the beets cover the ground as shown in this picture, cultivation ceases.

season in this region is not long enough to permit part of it to be wasted by allowing the bets to stand still for lack of water. If beets are suffering from want of water and a rain comes, none of the farmers would think of its doing any harm to the bets, yet some were of the opinion that an irrigation would harm the beets.

After irrigation is begun, it is usually necessary to continue to irrigate every 10 to 20 days from the time of the first irrigation until about the first of September. To know how to irrigate, the grower must know his soil well, and he must study the condition of

his crop each year. The limit to the supply of available water must also be known, and the water must be so used that it will be properly distributed. The fact remains that the water must be used when it is delivered in the ditch. It may not always seem best for any given farm, but as there are many farms under the ditch each must take the water when it is available.

Irrigation usually proceeds day and night when the water is available, the average man putting in long hours in the operation. Some men turn the water on alfalfa fields at night, but most men set the water on long rows of beets and let it run all night. This sort of work demands that the water be set to running just before dark at night and changed as soon as day breaks in the morning. Many of the men stay in the field 14 or 15 hours a day when irrigating.

As already stated, irrigation is very distinctly an operation that is different for each farm. Some men can irrigate 5 or 10 acres per day and do it better, more efficiently, and easier than they could irrigate 2 acres on another farm. The head of water and the lay of the land cause part of this variation. It pays to irrigate carefully and not hastily. One should prepare his land so that there will be no low places where water will collect and stand.

The average labor cost of irrigation in the area studied is 61 cents per acre per irrigation; this means that the average man can irrigate about 4 acres in 12 hours. Four or five acres per day of about 12 to 15 hours can be covered when the water is running about all the time, day and night. The average man irrigated his beets 2.4 times; 26 men irrigated once, 168 irrigated twice, 89 irrigated three times, and 14 irrigated four times. The available data comparing the crop yields and the number of irrigations failed to show any manifest correlation. In order to form definite conclusions upon this subject, more detailed information as to time and number of water applications would be necessary, and types of soil and other considerations would have to be studied much more closely than was possible for the men gathering the data of this survey. Very little is known by the average farmer as to the quantity of water applied to each field or the quantity wasted, as he has no measuring devices for individual fields. The water is measured out of the main canal, but after that the farmer makes no accurate measurements.

These studies, made in 1915, show that detailed information was gathered from 301 farms upon which 8,745 acres of sugar beets were irrigated, the man labor expended upon each acre being 7.43 hours, at a cost of $1.49.

Four men did not irrigate their beets. These in all cases were beets on seeped or subirrigated lands. About 99 per cent of the total area planted to beets was irrigated. The nonirrigated lands of the

region are not adapted to the production of profitable crops of sugar beets.

LIFTING PRACTICE.

Nearly 91 per cent of the growers used 3-horse teams to lift beets, as they all used crotch 1-row lifters. None used 2-row or side-row lifters. Lifting is an arduous operation when the season is such that the fields become very dry; and it would seem that the different types of soil would make corresponding differences in the amount of labor necessary to lift the beets, but in this region it seems that the same number of horses is used in most cases. There is, however, a variation in the acres pulled per day by the crews of different farms.

It is not customary to keep the lifter going the entire day, as a man lifting with three horses can lift during the average 10-hour day 2.29 acres of beets. The average man has not enough horses to haul so many beets per day in addition to the lifting work, so the custom is to lift and pile and top only as many beets per day as can be hauled in a day. If beets lie in the field after being lifted or topped there is considerable loss in weight unless they are exceptionally well covered. Covering them over with leaves when they are in small piles will stop the evaporation to some extent, but the leaves soon wilt and are of little protection. Farmers try to avoid having to cover beets in the field.

On account of the danger of freezing, the farmers are always anxious to get all the beets out of the ground as soon as possible after harvesting begins, and this season is perhaps the busiest of the year. Beet pulling usually begins about the first of October and lasts until November. As a rule, November 5 is considered the latest safe date to have beets still in the ground. The men who get through early are usually hired by those with larger acreages. Very little other work is done after beet harvesting begins until the harvest is finished.

It required 4.41 hours of man labor and 13.09 hours of horse labor to lift the average acre of beets harvested, the average cost of the same being $2.18 per acre.

HAULING BEETS.

The hauling of the beets is one of the hardest operations in the production of the sugar-beet crop. The beets are always hauled when there is a rush to get work done, as there is danger of loss of beets if they are not harvested before the ground freezes. Harvest begins about October 1 and should be completed by November 5 to be safe from loss by freezing. In some seasons it is possible to

harvest after this date, but in other years the ground will be frozen so that it is very laborious or impossible to harvest the beets. Allowing for some wet or bad weather, it will be seen that beet harvesting is the rush season of the year.

Although labor at hauling beets is always paid a higher rate than other farm labor in this region, in estimating the cost of hauling the usual rate of 20 cents per hour for man labor and 10 cents per hour for horse labor is used as the basis in this bulletin. For hauling beets men get from $50 to $75 a month and board, according to the need the farmers have for labor.

Beets are hauled in special wagon boxes, which permit the beets to be dumped from the wagon directly into the cars that are to transport them to the factory. (Fig. 7.) The men do not have to shovel the beets when cars are available, but in many cases the number of

FIG. 7.—Loading and hauling sugar beets. Wagons are specially constructed to dump the load directly into a freight car or storage sheds.

beets harvested exceeds the quantity that can be stored at the factory, so the beets are piled at the dumps in large piles on the ground. Sometimes 5,000 tons are put into one pile. These piles are made about 8 feet high and of various widths and lengths. No extra compensation is provided for this piling of beets at the dumps.

Usually one man loads and unloads his beets at the dump, but in some cases the farmer has a man in the field who helps load the wagons, doing other work while the wagon goes to the dump.

These studies, made in 1915, show that detailed information with regard to hauling sugar beets was gathered from 305 farms, from which the product of 8,817 acres of beets was hauled, requiring an average of 10.36 hours of man labor and 29.66 hours of horse labor per acre. The cost of hauling was therefore $5.02 per acre, or 47 cents per ton.

The fact that hauling is done for less per ton with two horses than with other sorts of teams is perhaps not entirely due to the efficiency of this method of hauling, but is more likely to be due to the fact that the men with the uphill haul or harder haul used more horses to a wagon than the men with easier hauls. The cost of hauling varies with the season and the condition of the fields and roads. For 1915 the load hauled averaged 3.18 tons. Two horses hauled on an average 2.82 tons, three horses 2.92 tons, and four horses 3.37 tons, the average cost of hauling being 26 cents per ton per mile hauled, when man labor is figured at 20 cents per hour and horse labor at 10 cents per hour. If better methods of loading and unloading were devised, and especially if improvement could be made in loading beets on the wagons, this cost could be greatly lessened.

The hired hauling on an average cost 28.3 cents more per ton than hauling done by the farmer, where his labor was figured at $2 per day per man and $1 per horse for a 10-hour day, and the average distance for the hired hauling was 1.3 miles less. This gives some indication of the scarcity of labor which usually prevails during the harvest season. The man who has not the horses for hauling beets must hire the necessary men with teams and must have the labor done during a short period of time, so he has to pay for this work at a rate that is higher than is common for other seasons of the year. Usually he does not furnish wagons or any harness, which would mean some expense for wear and breakage. The average cost was $4.81 per acre for hauling the beets where the farmer did the work, counting labor only, and $7.85 for hired hauling, a difference of $3.04. In computing the cost of hauling 1 ton of beets 1 mile it was found that for farmers doing their own work in the first group, those averaging 0.76 of a mile, the average cost was 49 cents per ton-mile. For the second group, those averaging a 1.67-mile haul, the cost was 28 cents per ton-mile; in the third group, those averaging a 2.91-mile haul, the cost was 19 cents per ton-mile; in the fourth group, those averaging a 3.96-mile haul, the cost was 17 cents per ton-mile. The hired hauling cost 69 cents per ton-mile on an average haul of 0.88 mile, 51 cents per ton-mile for an average haul of 1.46 miles, and 36 cents per ton-mile for an average haul of 2.83 miles. The difference of 21 cents between groups 1 and 2 and 9 cents between groups 2 and 3 for farmers doing their own hauling might be taken as an indication that the average cost of loading beets was about 12 cents per ton; but this is not an accurate method of figuring, as the actual time taken to load the beets was not recorded. Table VIII, showing the cost of hauling according to distance, indicates that it costs the farmers in the group farthest from the dump an average of $3.11 more per acre to deliver their beets than those in the group closest to the dump.

In other words, the additional cost is about $1 per acre for each mile of distance from the dump. In the case of hired hauling this additional difference is more nearly $2 per acre for each mile from the dump.

TABLE VIII.—*Cost of hauling sugar beets in the Billings region of Montana in 1915.*

Classification.	Number of farms.	Beets hauled.	Average cost of hauling.	
			Per ton.	Per acre.
Hauled by grower:		*Tons.*		
Less than 1½ miles (average 0.76 mile)	112	39,220	$0.37	$3.98
1½ to 2½ miles (average 1.67 miles)	100	29,544	.463	4.98
2½ to 3½ miles (average 2.91 miles)	65	18,337	.544	5.85
3½ miles and farther (average 3.96 miles)	12	3,788	.650	7.09
All farms [1] (average 2.86 miles)	289	90,899	.447	4.81
According to the size of the crew:				
1 man, 2 horses	120	34,897	.402	....
1 man, 3 horses	30	8,521	.498	....
1 man, 4 horses	118	37,859	.46	....
3 men, 8 horses	11	5,021	.52	....
Mixed	10	4,591	.52	....
Total [1]	289	90,889	.447	....
Hired hauling:				
Less than 1½ miles (average 0.88 mile)	4	847	.61	6.56
1½ to 2$\frac{1}{16}$ miles (average 1.46 miles)	12	3,888	.75	8.07
2½ to 3$\frac{1}{16}$ miles (average 2.83 miles)	3	137	1.00	10.76
All hired (average 1.55 miles)	19	4,872	.73	7.85

[1] Excluding 19 farms from which the hauling was done under contract, as shown in the last part of the table under "Hired hauling."

HAND OR CONTRACT LABOR.

The labor on the sugar-beet crop that is done by hand without the use of machinery consists of blocking, thinning, two hoeings, and pulling, piling, and topping the beets. About three-fourths of this labor in the Billings region is done by contract. The labor contractors make an agreement with the farmer to do all the handwork on the crops, receiving therefor a definite sum under a system which makes it to the interest of the contractor to cover as large an acreage as possible per day. Some growers try to counteract the tendency toward careless work by paying a bonus to the workers if the beets yield more than a certain tonnage per acre. This bonus system is not in general use, not having reached any definite or satisfactory basis, but it has features which recommend it. The basis now varies according to the different ideas as to what it should be.

In cases where there is any disagreement, the factory agricultural force supervises and looks after the fulfillment of the contracts between the farmers and the laborers. Most of the contract laborers in this region are Russians or Belgians.

A great deal of this work is done by the children of the families of the men doing the hand labor. Women also are employed in the

fields at this work. The work of thinning, which requires the worker to stoop or crawl along the beet row, is performed by boys or girls about 15 years of age, in many cases more efficiently than by men. In figuring the costs for this labor, children who are able to do full work have been allowed the same rate per hour for labor as men. All the labor is estimated on the basis of what a man can do per day. There is no indication that men who do their own beet thinning get better crops than those who have the thinning done under contract.

Of the 305 farms in the entire study, on 227 farms a whole or part of the hand labor was contracted for at a definite rate per acre for the work. The area worked in this manner was 6,399 acres, at a cost to the farmer of $18.53 per acre for all hand labor, which includes thinning, hoeing, topping, etc. On 91 acres the contract was for blocking and thinning only, at an average price of $6.89 per acre. On 123½ acres the contract was for piling and topping only, at an average cost of $9.14 per acre. There were no farms where hoeing was contracted for as a separate operation. (Table IX.)

TABLE IX.—*Average requirements and cost per acre of hand labor on the sugar-beet crop in the Billings region in 1915.*

[Hand labor is figured at 20 cents per hour.]

Kind of work.	Labor done by grower.		Labor contracted.		Average for each acre planted.	
	Hours.	Cost.	Hours.	Cost.	Hours.	Cost.
Blocking and thinning	36.9	$7.38	30.9	$6.18	32.25	$6.45
First hoeing	15.5	3.09	10.3	2.06	11.5	2.30
Second hoeing	7.9	1.59	5.15	1.03	5.8	1.16
Pulling and topping	36.5	7.30	46.30	9.26	43.65	8.73
Total	96.8	19.36	96.65	19.53	93.2	18.64

The general impression in the Billings region is that the contract laborers get a good price for the work of thinning, topping, etc., but the good daily wage is due largely to the fact that they work rapidly so as to complete the thinning before the beets are very large, and that they work very long days. The thinner averages from 12 to 14 hours per day; this is especially true of the contract laborers. Some of these workers become very expert, being able to block and thin an acre of beets in two days; some even exceed this rate.

Growers who do their own hand labor are in most cases men who have large families and who have had experience as contract beet workers. They are usually of foreign birth. It is very common for a man to come into the region and work a few years as a contract laborer and then rent or buy a farm and begin to work for himself. These men who are successful in saving enough money to begin farming for themselves are usually the most industrious of the contract laborers. Having had experience in handling the crop, they usually grow rather large acreages of beets.

COST OF SEED FOR SUGAR BEETS.

The seed for the sugar-beet crop is furnished to the farmer by the sugar company contracting for the beets. This seed has been sold to the farmers at 10 cents per pound for a number of years, and the quantity of seed per acre is often specified. Most farmers plant the amount per acre that the company specifies; therefore the cost per acre for seed runs very nearly the same for each farm. The cost of seed per ton of beets produced is very variable, as there is variation in the tonnage per acre. For individual farms the cost of seed per ton of beets produced varied from 10 cents to more than 60 cents. Detailed information gathered from 305 farms growing 8,849 acres of beets is as follows: Pounds of seed per acre, 17.2; cost of seed per pound, 10 cents; cost of seed per acre, $1.72; cost of seed per ton of beets produced, 16 cents.

COST OF MACHINERY.

The cost of machinery varies greatly in accordance with the amount of machinery the man owns and the area of beets that he cultivates. Some growers had high-priced machinery and a small area in beets, so the cost of machinery per acre ran very high; in some instances it was more than $15 per acre. To grow a crop of beets, a farmer should own the machinery or be able to rent certain machines when needed. To own all machinery is not always advisable where the area in beets is less than 10 acres.

The depreciation of machinery on various farms varied from 10 to 25 per cent of the original value, depending on the acreage of beets to be tended by one machine and the type of machinery owned. The grower should either own or have the use of the following machinery: Plow, harrow, level, beet drill, beet cultivator, beet wagon (with box of a special type for the automatic dumping of the beets), beet puller, hoes, shovels, topping knives, and beet forks. In some cases a roller and a manure spreader should be added to this equipment.

It is rather hard to get an exact figure for the cost of machinery for beets, as farmers use the same wagons, harrows, plows, etc., on other crops, and allowance for this has to be made; but it is possible to get a reasonably accurate estimate of the depreciation and repair cost of machinery that is chargeable to beets by comparing the acreage in other crops. These charges were figured separately for each farm, and Table X shows the results of the data furnished by 305 farmers as to the costs chargeable to the sugar-beet crop for the use of machinery.

Table X is necessarily more or less of an approximation, and there may be some items of cost not enumerated; however, the costs were

obtained in a manner which should include the correct total cost of machinery for beets during the season of 1915.

TABLE X.—*Cost of machinery for growing sugar beets in the Billings region in 1915.*

Items of cost.	Total.	Per farm.	Per acre.	Per ton of beets.	Percentage charge.
Repairs	$5,671	$18.59	$0.64	$0.06	24.2
Depreciation	10,393	34.08	1.17	.11	44.3
Interest on investment at 8 per cent	6,678	21.89	.76	.07	28.8
Hired machinery	637	2.09	.07	.01	2.7
Total cost	23,379	76.65	2.64	.25	100.0

PRORATING INTEREST ON THE INVESTMENT.

Detailed information covering the cash investment in 305 farms on which 8,849 acres of sugar beets were grown showed an average of $3,656 per farm, and the prorated interest cost chargeable to the beet crop was $11.99, being an average of 41 cents per acre planted to beets and 4 cents for each ton of beets produced.

The average man pays about 41 cents per acre for interest on money invested in the beet crop. This is only for money spent for labor and miscellaneous items of cost, the greater part being for money paid to contract laborers or hired labor. Contract laborers receive about half of their contract price at a time soon after the blocking and thinning is done. For this region this averages about $9 per acre, and in most instances it is paid some time in June or July, although in some cases it is advanced to the laborer earlier in the season. No money is received from the beet crop until October or November, so the interest on money paid for hand labor runs for four to six months.

Interest on contract-labor money for four to six months at 8 per cent for $9 is 24 cents to 36 cents per acre, depending on the time the contractor receives the money. Interest on money paid to the farm laborers for one to eight months, depending on the number of laborers hired, varies on different farms from nothing to 60 cents per acre of beets grown.

COST OF LAND FOR SUGAR BEETS.

The owner's cost for land is divided between interest, irrigation water, and other items that are furnished by landlords on rented farms. These items aggregate $11.99 per acre, divided as follows: Interest on real estate, $9.86; land taxes, $1.15; cost of water for irrigation, 86 cents; miscellaneous charges, 12 cents. (Table XI.)

TABLE XI.—*Apportionment of interest, taxes, and charges for irrigation water for growing sugar beets on rented lands and owned farms in the Billings region.*

Classification of farms.	Number of farms.	Acres of beets.	Cost for land.		
			Total.	Per acre.	Per ton.
All farms	305	8,849	$104,931	$11.85	$1.10
Beet lands:					
Cash-rented		1,620	15,226	9.25	.85
Share-rented		3,801	49,071	12.91	1.28
Owned		3,428	41,098	11.99	1.04

The charges pertaining to owned lands are figured on the estimated value of the land planted to beets, with interest at the rate of 8 per cent. Lands under cash rentals are figured on a similar basis as to the value of the land in beets and the value of other lands on the farm, so as to charge the proper amount for beet lands. Lands under share rentals are figured on the basis of the value of the share of beets and beet tops that the landlord receives. This may be a little high when considered from the basis of the landlord's expectation that the beet-land rental will bring up the average rental of the farm which has a considerable acreage in grains and hay, on which a less rental per acre is paid to the landlord. The usual share of the beets paid for rental is one-fifth of the crop, and in many cases the landlord requires that a certain acreage of land be planted to beets. The tops are divided in various ways, there being no prevailing method as to the division.

Share renters on a few farms gave the landlord as much as one-half of the crop for rental; but in all of these cases the extra rental was for some special expense borne by the landlord, such as furnishing seed, part of the contract labor, a supply of manure, or the equipment and work stock. Under such conditions allowances were made for these extra items furnished, and this amount is properly deducted from the landlord's total charge, as the tenant in such cases is giving part of the crop for something else than the land on which to grow it, and the landlord is paying other expenses than those properly called land charges. These special rentals are not common, and in most cases the landlord, being responsible for the success of the crop, usually demands a good return for his investment. The tenants on such farms are often men who have very little capital, and they would be unable to handle farms of any size unless provided with some outside capital.

Cash rentals are much lower than the share rentals, owing to the small risk taken by the landlord, who is certain of a definite income from the farm; but the landlord who rents land for a share of the

crop does not get much if the farm is badly handled or if the crops are poor from any cause. Most of the cash-rented farms are owned by absentee landlords, while many of the share-rented farms are owned by farmers who live in the region and can supervise their farms to some extent.

The average value of the owned beet lands is $123.60 per acre, and with interest at 8 per cent this item is by far the heaviest in the list of costs of land for beets. The valuation given for share-rented lands was $126.91 per acre and for lands that were rented for cash the value was given as $134.19. These values are based upon the sale value as estimated by the man operating the farm. The average value of all sugar-beet land studied in the Billings region was $126.95. Assuming that the cost of water for irrigation and the cost of taxes and miscellaneous items are the same for landlords as was found for owners of beet lands (a total of $2.13 for these items), the landlords of the region have an average of $7.36 per acre for interest on cash-rented lands and $11.98 for interest on share-rented lands. This amounts to interest at 5.5 per cent on the value as given per acre for cash-rented lands and interest at 9.4 per cent on the value of share-rented lands.

RELATION OF YIELDS TO COST AND PROFIT.

Seemingly there is the most profit in a crop of beets of about 14 tons or over per acre in the Billings region. The average profit per acre, as shown by this study, is the same for yields of more than 14 tons, but this should not be taken to indicate that to increase the yields on this land so as to produce more than 14 tons is to incur an expense that may not return a profit over and above the cost of the extra labor. High yields per acre seem to be associated with higher profits per acre. Most growers getting large yields are men who use much manure on their beet lands, and it is not correct to state that they do not get a profit on increasing the yields, as they find employment during a time they might otherwise be idle and have idle teams. In figuring the cost, allowance has been made for the yard value of the manure and regular prices paid for labor. The labor which is done in the winter and early spring is profitable, as no profit would otherwise be shown. Horse labor especially will show a profit, as the teams would cost about the same for keeping whether they were worked or not, and usually the work is not hard. To disregard these facts and figure on the actual cost might warrant the conclusion that increased yields are not profitable. It would be difficult to give any definite yield as the limit of profitable attainment, but it is reasonable to assume that it is higher than any of the yields produced, and perhaps many tons higher. The growers

who showed a loss on beets yielding over 12 tons per acre were only three in number and grew only small areas, averaging less than 6 acres each. Each had used heavy applications of manure and had given it a value of $1 per ton in the yard; the investment in machinery was also high in each case. The average cost for their machinery was nearly $12 per acre, while the average for the region was $2.64 per acre. Unless land is capable of yielding better than an 8-ton crop of beets it is advisable not to plant beets on it, but to plant some crop that will not require so much labor for production. Cheap and poor lands are not adapted to beets or any crop that requires much labor per acre. The only case where a man can afford to grow beets on land that does not produce well is where he owns the land and is trying to eradicate weeds by careful cultivation. He must have some return other than that received from the beet crop. If the grower is willing to work for less than the price figured in this bulletin as the cost of growing beets or is an exceptional manager of labor he can make a return from a beet crop that is less than 8 tons an acre, but it is an uncertain speculation. It is admitted, however, that there are many exceptions and that some men can show a profit from a small yield, as they are growing the beets at a time when they would otherwise be unemployed. Beets afford a means whereby the farmers of this region are able almost to double the length of the season that they have field work to do, for there is no other common row-tilled crop, and hay and grain farming does not afford labor early in the summer at beet-cultivation time or late in the autumn when beets are to be harvested. A farmer's profits often depend on the length of the season of crop labor. There is no doubt that on a larger area the cost per acre for machinery would average less, as the investment total would need to be no larger. If these men were able to pay for labor and get a return for the manure used, there is no doubt that their loss is only a figurative one. If they had allowed only 50 cents per ton for the yard value of manure they would have shown a profit on their beets, as the average loss per acre was very small.

A few growers made a small profit per acre on beets that yielded about 8 tons per acre, and one that had a yield of 7 tons made a small profit. None of these men had any charge for manuring, and most of them were share renters. All reported rather rapid work and did not go over the ground a very great number of times. More than half of them did their own hand labor and reported doing it at a rapid rate, and the charge for hand labor in some of these cases was not over $12.50 per acre. These men show that in rare instances where the land is not hard to handle and the man works very rapidly it is possible to show a profit on beets that yield 8 tons per acre, but this is not possible in most cases and not possible on small areas

where the fields are small and there is much turning to do. Few of these men had small areas, their average acreage being above 30.

The average yield per acre on the 305 farms covered by this study was 10.76 tons, and the information gathered indicates that a yield of 8.87 tons per acre is required in order to pay expenses. There was a loss on 2,019 acres (22.8 per cent of the total acreage) and a profit on 6,830 acres (77.2 per cent of the total acreage). (Table XII.)

TABLE XII.—*The cost and profit from sugar beets as related to yields per acre and to acreage per farm in the Billings region in 1915.*

Classification.	Percentage of total acreage.	Per acre.		Per ton.		Percentage of acreage showing a profit.
		Cost.	Profit.	Cost.	Profit.	
Yields per acre:						
4 tons and less	1.71	$43.13	−$19.66	$12.59	−$5.74	None.
4.1 to 5 tons	3.14	45.18	− 12.66	9.20	− 2.56	Do.
5.1 to 6 tons	3.76	46.91	− 7.20	7.87	− 1.21	Do.
6.1 to 7 tons	3.54	51.36	− 5.90	7.46	− .86	1
7.1 to 8 tons	8.53	51.52	− .56	6.50	− .07	57.7
8.1 to 9 tons	8.59	55.85	1.45	6.26	.16	66.1
9.1 to 10 tons	13.39	55.87	6.58	5.64	.66	77.3
10.1 to 11 tons	11.90	56.07	12.84	5.14	1.18	96.8
11.1 to 12 tons	17.30	59.93	16.34	5.00	1.36	99
12.1 to 13 tons	11.63	58.61	23.48	4.58	1.83	100
13.1 to 14 tons	6.35	60.47	28.15	4.32	2.02	97.7
14.1 to 15 tons	7.13	65.40	28.55	4.36	1.91	100
15.1 to 16 tons	2.40	64.64	33.95	4.06	2.13	100
16.1 tons or more	.63	77.10	30.91	4.55	1.83	92.6
Total	100	56.79	11.70	5.28	1.08	77.2

Classification.	Average area.	Number of farms.	Per acre.			
			Yield.	Value.	Cost.	Profit.
Area in beets per farm:	*Acres.*		*Tons.*			
5 acres or less	4.6	10	11.7	$74.80	$74.46	$0.34
6 to 10 acres	8.7	37	10.3	66.83	60.95	5.78
11 to 15 acres	13.2	26	10.8	69.08	62.21	6.87
16 to 20 acres	18.1	41	10.4	66.17	58.12	8.05
21 to 30 acres	26.0	79	10.7	68.82	55.63	13.19
31 to 40 acres	36.6	59	10.8	68.76	56.48	12.28
41 to 50 acres	46.2	27	11.0	70.10	56.18	13.92
51 to 60 acres	55.5	11	10.8	67.33	53.94	13.39
Over 60 acres	88.6	15	10.5	67.19	55.82	11.37
Total	29.1	305	10.76	68.49	56.79	11.70

Table XII indicates that the acreage of beets per farm had little to do with the yield per acre but had much influence as to the profits per acre within certain limits. It appears that each farmer should plant at least 20 acres of beets in order to have them grown most economically. Above 20 acres there seems to be but slight variation in the cost of production or profits per acre.

SUMMARY.

(1) The data gathered from 305 farms in the Billings region of Montana give the total hours of labor required to produce beets and the other costs of production for the season of 1915. (Table XIII.)

TABLE XIII.—*Summary of labor requirements for the production of sugar beets.*[1]

[Man labor is rated at 20 cents per hour and horse labor at 10 cents per hour.]

Kind of labor.	Average per acre worked.			Average per acre of all sugar beets studied.		
	Cost.	Man.	Horse.	Cost.	Man.	Horse.
Farm labor:		*Hours.*	*Hours.*		*Hours.*	*Hours.*
Manuring	$3.31	8.90	15.30	$1.21	3.27	5.59
Plowing	2.54	4.59	16.18	2.90	5.23	18.55
Crowning alfalfa	2.48	4.35	16.14			
Disking	1.09	1.84	7.19	.23	.39	1.52
Rolling land	.29	.71	1.49	.08	.20	.41
Floating	.89	1.31	5.96	.87	1.47	5.80
Harrowing	.93	1.75	5.75	.93	1.75	5.75
Cleaning ditches	.13	.32	.61	.12	.32	.60
Planting seed	.40	1.00	2.00	.40	1.00	2.00
Rolling	.31	.77	1.55	.17	.43	.86
Cultivating	1.74	4.46	8.46	1.74	4.46	8.46
Furrowing	.39	1.00	1.89	.39	1.00	1.89
Irrigating	1.49	7.43	....	1.47	7.34	....
Lifting	2.18	4.41	13.09	2.18	4.41	13.09
Hauling	5.12	10.36	29.66	5.02	10.36	29.66
Total	23.19	53.40	125.27	17.71	41.76	94.18
Hand labor:						
Blocking and thinning	....	....	....	6.45	32.25	....
Second hoeing	....	....	....	2.30	11.50	....
Third hoeing	....	....	....	1.16	5.80	....
Pulling and topping	....	....	....	8.73	43.65	....
Total	....	....	....	18.64	93.20	....

[1] In the columns headed "Average per acre worked" are given the average cost and labor expended on each acre for each operation, computed on the number of acres covered by each operation. In the columns under "Average per acre of all sugar beets studied" the total surveyed acreage (8,849) is the basis of computation.

The aggregate of overhead charges for the entire area was $20.44 per acre, divided as follows: Land charges, $11.85; manure, $3.79; machinery, $2.64; seed, $1.72; cash to run farm, 41 cents; miscellaneous, 3 cents.

The total cost of sugar-beet production as herein shown is $56.79 per acre, divided as follows: Farm labor, $17.71; hand labor, $18.64; overhead costs, $20.44.

The grower can apply these data to the present requirements by adjusting them to the present prices of labor, real estate, equipment, and the value of beets produced. There have been no changes of note in the labor requirements of production.

(2) The information obtained indicates that the growing of sugar beets can not be profitable in this region unless a yield of more than 8 tons of beets per acre is produced. It is also shown that each farmer should grow at least 20 acres for most economical production.

(3) Of the total area in sugar beets, 77.2 per cent of the acreage was grown at a profit.

(4) The average acre of the region devoted to sugar beets returned a profit of $11.70 after paying the cost of production.

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"IN THE FIELD OF AGRICULTURE we have agencies and instrumentalities, fortunately, such as no other government in the world can show. The Department of Agriculture is undoubtedly the greatest practical and scientific agricultural organization in the world. Its total annual budget of $46,000,000 has been increased during the last four years more than 72 per cent. It has a staff of 18,000, including a large number of highly trained experts, and alongside of it stand the unique land-grant colleges, which are without example elsewhere, and the 69 State and Federal experiment stations. These colleges and experiment stations have a total endowment of plant and equipment of $172,000,000 and an income of more than $35,000,000, with 10,271 teachers, a resident student body of 125,000, and a vast additional number receiving instruction at their homes. County agents, joint officers of the Department of Agriculture and of the colleges, are everywhere cooperating with the farmers and assisting them. The number of extension workers under the Smith-Lever Act and under the recent emergency legislation has grown to 5,500 men and women working regularly in the various communities and taking to the farmer the latest scientific and practical information. Alongside these great public agencies stand the very effective voluntary organizations among the farmers themselves, which are more and more learning the best methods of cooperation and the best methods of putting to practical use the assistance derived from governmental sources. The banking legislation of the last two or three years has given the farmers access to the great lendable capital of the country, and it has become the duty both of the men in charge of the Federal reserve banking system and of the farm-loan banking system to see to it that the farmers obtain the credit, both short and long term, to which they are entitled not only, but which it is imperatively necessary should be extended to them if the present tasks of the country are to be adequately performed. Both by direct purchase of nitrates and by the establishment of plants to produce nitrates, the Government is doing its utmost to assist in the problem of fertilization. The Department of Agriculture and other agencies are actively assisting the farmers to locate, safeguard, and secure at cost an adequate supply of sound seed. The department has $2,500,000 available for this purpose now and has asked the Congress for $6,000,000 more."—*From President Wilson's Message to Farmers in Conference at Urbana, Ill., January 31, 1918.*

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

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Degeneration in Potatoes

BY

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UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

BULLETIN N[illegible] APRIL, 191[illegible]

Degeneration in Potatoes

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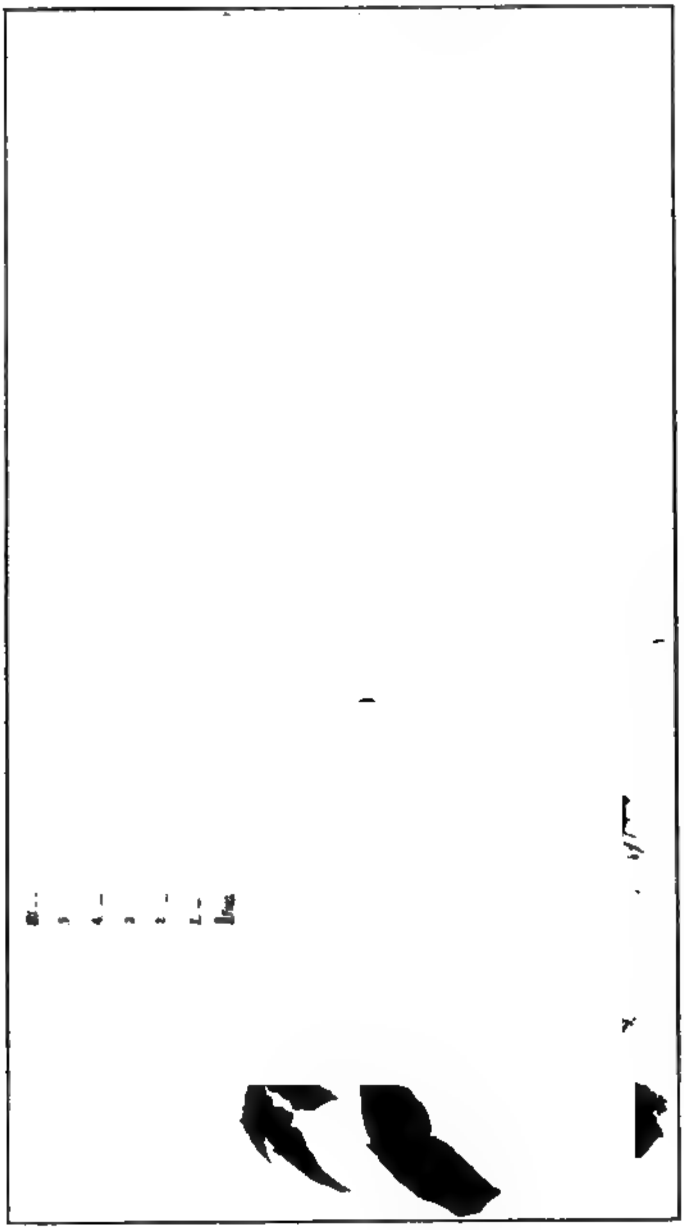

FIG. 1.—Left: Intermediate degenerate Russet Burbank plant about eight weeks from planting. Right: Normal-vigorous Russet Burbank plant about eight weeks from planting.

FIG. 2.—Characteristic vine development in "yellow-top" degenerate.

a very helpful nature. Tuber-line* selection plots and special seed plots in which something over fifteen thousand tubers have been planted on the tuber unit** plan have furnished material for real study. During this five-year period from four to eight acres of experimental plots have been grown annually, partly under irrigation and partly under non-irrigated conditions. During the past three seasons, the performance of 316 selected tuber lines has been recorded and this work in particular has thrown much light upon the subject of degeneration. Within these lines degeneration has been very common and their three-year performance records furnish much evidence of the rate of deterioration and the consistent downward trend once degeneration sets in.

SPINDLE-SPROUT

Spindle-sprout has not been a serious problem in our potato work, although such degenerates have occasionally appeared within

*The term "tuber-line selection" is here applied to a special selection or variety population arising from a single tuber.

**Potatoes are said to be planted on the tuber unit plan when all the seed pieces from each seed tuber are planted in adjacent hills.

plots being grown for table stock as well as in special seed plots. In most cases these have appeared suddenly or at least we have not been able to identify in the field, plants, the tubers of which would

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FIG. 3.—Showing nature of tuber development in "yellow-top" degenerates.

in the rest period was the real cause of this degeneration which apparently took place suddenly we would not care to say but the circumstances are suggestive. Possibly in choosing these tubers we had in mind a type ideal more or less closely correlated with spindle-sprout. But among many tuber units selected much upon the same tuber characteristics and stored under the same conditions, barring the break in the rest period, no spindle-sprout degenerates have appeared. In each case these selections were shallow-eyed tubers of medium size and average length for the variety. In other words, they were what most growers would consider ideal variety types. While we once attempted in a preliminary way to demonstrate the possibility of inducing spindle-sprout by treatment similar to that described above and failed, we still feel that it is a wise

FIG. 5.—Leaf on the right from a normal-vigorous Russet Burbank plant. Leaf on the left from an intermediate degenerate type. Note the smaller size and tendency to crinkle.

precaution in all our experimental work to avoid any disturbance to the normal rest period of potato seed.

Under the general heading of spindle-sprout, it would seem most logical that we present observations upon a certain degenerate type of vine which we have always recorded in our notes as "yellow-top." Such plants have appeared more or less abundantly every year in both irrigated and non-irrigated plots. They have been particularly numerous in very dry seasons in plots grown without irrigation. These plants appear in various stages of vigor from almost normal stature with yellow tips to quite dwarf types with the yellow color spreading to all parts of the vine. The more vigorous type is well

illustrated in figure 2. Such plants are more compact or upright in their habit of growth and the tips of the branches carry leaves abnormally small with a characteristic yellow cast. In extreme cases of degeneration, the plants are quite dwarf and resemble very closely typical mosaic degenerates as described by other investigators. Tuber development is, on the other hand, rather typical of that of plants described by others as affected with leaf-roll. These yellow-top plants produce few if any tubers of marketable size; in fact, tuber development is far from normal, as illustrated in figure 3. The tendency is for one tuber to form on the tuber stem and then for another stem to push out from the tip of this tuber, forming another small tuber, this process frequently being repeated until a chain of small tubers is formed or until the tuber stem emerges from the surface of the soil as a leafy branch. Such degenerate types apparently appeared very suddenly. So far as we have been able to determine, there are no intermediates of one season, the

FIG. 6.—Mature normal vigorous Blue Victor plant.

progeny of which are the next season a more advanced degenerate or yellow-top type.

Since this degenerate type is not an uncommon one under local conditions, it was planned in the fall of 1911 to save seed from typical yellow-top plants to be planted for the purpose of observing whether the progeny would be similarly affected. Seed was chosen from the more vigorous type of vine, as that illustrated in figure 2. This was partly from choice and partly from necessity. Seed was selected from the more vigorous type, chiefly because we wished to determine whether the progeny would show more advanced degeneration. On the other hand, yellow-top plants noticeably dwarfed seldom produced a tuber weighing more than a third of an ounce, so it was difficult to secure seed from such plants large enough to plant. From the same plots seed of normal size was selected to be tested in 1912 with this seed from yellow-top plants. The tubers were selected after the digger and, judging from their size, must

FIG. 7.—An intermediate degenerate or semi curly-dwarf Blue Victor plant.

FIG. 3.—A typical early-dwarf Blue Victor.

have come from plants apparently normal. This seed was selected from plots of Early Michigan, Early Triumph, and Irish Cobbler grown without irrigation; also from plots of Early Six Weeks growing in an excellent irrigated environment. In the case of the non-irrigated plots, the moisture supply was not sufficient for good vigorous vine growth nor for ideal tuber development. The plants wilted more or less during the warmer part of the day, both during the setting period and while the tubers were making their early growth. Later in the season the moisture conditions improved and the plots produced a fair crop of marketable potatoes. Under such unfavorable conditions this degenerate type was quite in evidence.

Seed selected from these yellow-top plants was planted in 1918 under irrigated conditions. Most of the tubers were small (1 to 2 ounces) and were planted whole, although a few were large enough (3 to 5 ounces) to be halved lengthwise. The seed germinated very well but all the plants were spindle-sprout degenerates of the worst type. One of these is shown in figure 4. From the entire plot of one-twentieth of an acre, not over fifty pounds of marketable tubers

FIG. 9.—Foliage of Blue Victor. A, normal-vigorous; B, semi-curly-dwarf; C, curly-dwarf.

were dug. From the plots planted with seed of normal size no spindle-sprouts and only a very, very few yellow-tops developed, although the total area of the plots exceeded one acre.

With spindle-sprout and yellow-top degeneration, as we have observed it, deterioration is apparently sudden and complete. Observations lead us to believe that both may result from improper handling in storage or may be brought on by unfavorable growing conditions. Regardless of the real occasion for their appearance, these degenerate types would not seem to be, under local conditions, serious factors in seed improvement work. They automatically eliminate themselves, for no careful grower would save seed such as produced by spindle-sprout or yellow-top plants. In all cases coming under our observations where these degenerate types have developed in plots planted on the tuber unit plan, and we have planted several thousand tubers in this way, spindle-sprout and yellow-top have always appeared in tuber unit groups. In other words, wherever potatoes were planted in a manner to permit of such observations all the eyes from a tuber produced plants alike in these degenerate tendencies.

MOSAIC

Some may question the wisdom of discussing yellow-top degenerates under the general heading of sprindle-sprout on the ground that the color of these degenerate types suggests mosaic. We must confess that under local conditions we have not been able to reach a decision as to just what constitutes mosaic degeneration. Among plants of Early Triumph there is a type of degeneration accompanied by a yellowing of the leaves which is entirely different from yellow-top. We have assumed that this is the typical mosaic of other investigators. In this variety, however, we question the advisability of characterizing these as mosaics when, aside from the coloring of the foliage, the plants appear and behave like typical curly dwarfs. Deterioration is apparently gradual and through intermediate types, as is curly-dwarf. May not this yellowing be considered a characteristic curly-dwarf coloring within certain varieties rather than a characteristic of mosaic degeneration? Possibly we have not observed typical mosaic degenerates but our supposed mosaics have in their behavior resembled typical curly-dwarfs, and are in this paper so considered.

CURLY-DWARF

Of the types of degeneration that have come under our observation, curly-dwarf is by far the most important. It differs from

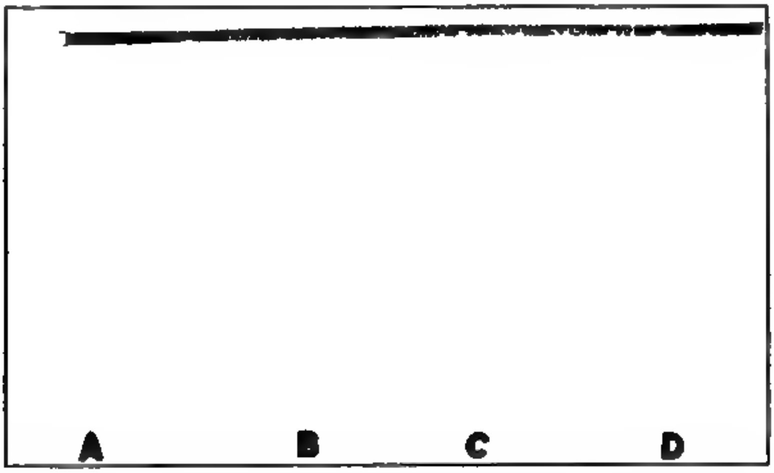

FIG. 10.—Variety, Howard Elliott. A, ventral, B, dorsal view of intermediate degenerate. C, dorsal, D, ventral view of normal-vigorous type. Notice in particular the depth of eyes on the tuber D as compared with A.

others in that it is clearly a gradual deterioration, the transition from normal-vigorous to curly-dwarf covering a period of two, three, or more seasons. Our observations lead us to believe that, as in other forms of degeneration, all plants from any tuber are alike; they are all normal-vigorous, all intermediates, or all curly-dwarfs. The first indication of degenerate tendencies is a slight crinkling and reduction in size of the leaf as illustrated in figure 5. Aside from the reduction in size of the foliage, these intermediate types often appear as vigorous as normal plants. The color of the foliage of curly-dwarf degenerates varies in different varieties. In Early Triumph the foliage takes on a yellowish cast. In the Early Ohio types, the foliage is lighter green and in typical curly-dwarfs the leaves are almost invariably browned or burned about the margins. In Green Mountain and Rural New Yorker the color is, if

FIG. 11.—Left: Russet Burbank tuber from normal-vigorous plant. Note the strong eyes and prominent eyebrows. Right: Russet Burbank tuber from intermediate degenerate. Many would consider this an ideal seed tuber. It weighs eight ounces. Note the shallow eyes and absence of eyebrows which are characteristic of these degenerate types.

anything, a darker green in the case of curly-dwarfs. The most reliable indicators of degeneration are loss of vigor and a tendency for the foliage to crinkle as illustrated ... and 8. Other illustrations of interest in connec... ...cussion on vine and foliage characteristics are sho... and 9. The legends under these figures are self-... ...ur hill and tuber-line selection work this type of ... been a real stumbling block. It has not only appe... ...st generation progeny of selected tuber units ... ...ppears among the progeny of the second and later ... ...er lines which were at first of the ... ...sing normal vigorous type.

To study the progres... ...warf degeneration and the yielding power of seed from ... varying stages, several special selections of seed have ... ...rom different varieties. From a block of Carman No. ... ...d in 1916 seed from vigorous, semi-curly-dwarf or int... ...nd curly-dwarf plants. This seed was planted in 191... ...ed of the same variety picked

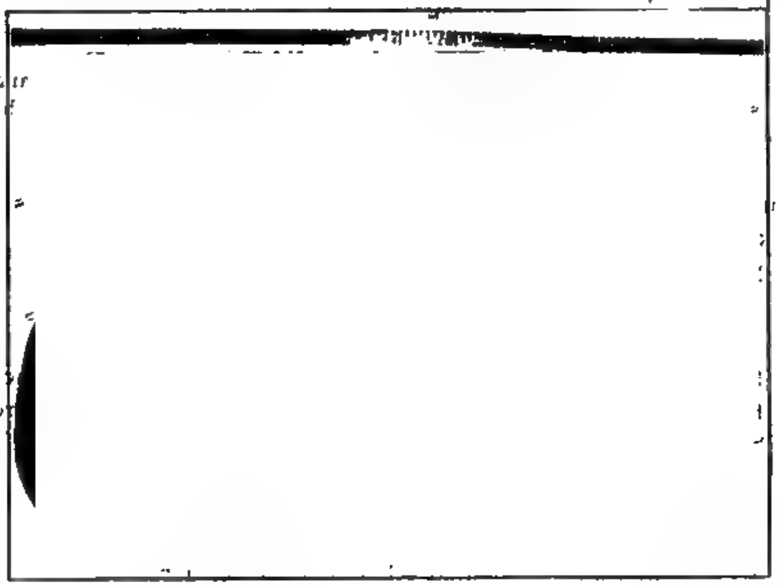

FIG. 12.—Degenerate types of Russet Burbank tubers. The weight ranges from four to eight ounces. While pretty to look at, their yielding power is not more than one-half that of such a tuber as shown at the left in figure 11.

FIG. 13.—Degenerate type of Carman No. 1 tubers. The weight ranges from six to thirteen ounces. The seed is attractive but it will not yield half a crop.

from the same block after the digger. The following yields of marketable tubers were secured:

Plot I—Seed from vigorous plants, 36,912 pounds per acre.

Plot II—Seed from semi-curly-dwarf plants, 18,317 pounds per acre.

Plot III—Seed from curly-dwarf plants, 19,930 pounds per acre.

Plot IV—Seed selected after the digger, 27,878 pounds per acre.

Seed from these four plots was selected after the digger in 1917 and again tested in 1918 with the following results:

Seed from Plot I yielded 19,212 pounds per acre.

Seed from Plot II yielded 6,435 pounds per acre.

Seed from Plot III yielded 4,104 pounds per acre.

Seed from Plot IV yielded 12,196 pounds per acre.

From a plot grown from seed purchased as Chas. Downing, which turned out to be really a strain of Rural New Yorker, we

selected in 1916 seed from vigorous, semi-curly-dwarf, and curly-dwarf plants. This seed was planted in 1917 but no record was kept of yields. Seed was selected from these plots after the digger in 1917 and tested in 1918 with the following results:

Yield from plot planted in 1917 with seed from vigorous vines, 13,985 pounds of marketable tubers per acre.

Yield from plot planted in 1917 with seed from semi-curly-dwarf vines, 1,626 pounds of marketable tubers per acre.

Yield from plot planted in 1917 with seed from curly-dwarf vines, 557 pounds of marketable tubers per acre.

From Mill's Prize, a strain of Green Mountain, selections were made in 1916 from vigorous and semi-curly-dwarf plants, as well as from the plot after the digger. This seed gave the following yields in 1917:

Seed from vigorous plants, 37,904 pounds per acre.

Seed from semi-curly-dwarf plants, 20,015 pounds per acre.

Seed selected after the digger, 27,413 pounds per acre.

Selections of seed from Blue Victor plots gave very similar results in 1917:

Seed from vigorous plants yielded 20,598 pounds.

Seed from semi-curly-dwarf plants yielded 11,973 pounds.

Seed from curly-dwarf plants yielded 9,825 pounds.

From these field tests, all conducted under irrigated conditions, we get a very good idea of the comparative yielding power of tubers from these three types of plants. The tests extending over a period of two seasons also indicate the progress of degeneration from year to year. The intermediates of one season are, as a rule, the curly-dwarfs of the next, while the tubers from curly-dwarfs of one season will, if planted the following season, produce practically no marketable tubers. Deterioration is slower in some varieties than others but the downward trend is nevertheless constant, and typical curly-dwarfs, so far as we have observed, are always the progeny of intermediate types.

From the three-year performance records of 108 Green Mountain, 108 Rural New Yorker and 100 Early Six Weeks tuber lines, which are to be published in full elsewhere, we have gathered much data which throw light upon this gradual downward trend of degeneration and abundant evidence of the existence of intermediate degenerate types. In tables I and III are presented the records of those

FIG. 14.—Good seed tubers produced by normal-vigorous vines of Carman No. 1. Weight, 20 and 22 ounces.

Green Mountain and Early Six Weeks lines that were described in the 1918 notes as typical curly dwarfs. Many of these individual records will show the gradual decline in yielding power, but the best evidence is found in the averages of the groups. In comparing the yearly average of the group of degenerate lines with the average yield of all lines of the variety for the season, it will be noticed that the former always falls below the latter, the difference being given in the last line of the tables. It will also be noted that the variation increases from year to year, indicating a gradual decrease in the yielding power of these degenerate types. In maintaining these lines, no effort has been made to eliminate degenerate types that have appeared within the population of many of these tuber lines. In fact special precaution has been taken to make seed selections representative of the whole population. By way of illustration it may be said that these tuber lines are maintained by planting each year twenty hills. Seed for these twenty hills is cut from five tubers, the four seed pieces from each tuber being planted in adjacent hills. When seed is selected in the fall for the plots of the

following year, one seed tuber is selected from each of these groups of four hills. In this way degenerate tendencies are sure to be perpetuated. To illustrate that such a system of selection has in many lines really resulted in deterioration we have grouped in tables II and IV those Green Mountain and Early Six Weeks lines in which the entire twenty hills were rated in the notes of 1918 as normal-vigorous. In comparing the average yield of these groups with the average yield of all lines of the variety, it will be seen

FIG. 15.—Row on the right (50A) the 1918 progeny of seed from normal-vigorous vines of 1916. Yield, 13,985 pounds per acre. Row on the left (51A) the progeny of seed from curly-dwarf plants of 1916. These are now in the final stage of degeneration. Yield 557 pounds of marketable tubers and 325 pounds of culls per acre. Variety, Rural New Yorker; seed secured as Chas. Downing.

that as a group the normal-vigorous lines have each year yielded above the average of all lines of the same variety. The variation between the averages of the two groups is given at the bottom of the table. Each year the difference between the two averages has increased, showing that degeneration has been a factor in reducing the average yielding power of the lines in the case of each variety. This decrease in the average yield of the total number of lines when compared with the lines still classed as normal-vigorous is most conspicuous in the case of Green Mountain where degenerate tendencies have been most pronounced.

CORRELATION BETWEEN DEPTH OF EYES AND DEGENERATION

Most interesting observations have been those bearing upon the correlation between depth of eyes and degeneration. In addition to the varieties Early Six Weeks, Green Mountain, and Rural New Yorker in which tuber line selection work has been carried on, observations have been noted upon others like Irish Cobbler, Early Triumph, Russet Burbank and Howard Elliott. Tubers from degenerate plants are, as a rule, shallow-eyed when compared with those from vigorous plants of the same variety. In practically all the varieties we have worked with, the ideal tubers, so far as depth of eyes is concerned, are the ones produced by either intermediate or curly-dwarf degenerates. We say ideal because they are popular on the market as table stock and conform to the popular notion of the ideal seed tuber. The most perfect tubers, so far as form, depth of eyes, and size are concerned, come from intermediate or semi-curly-dwarf plants. The progeny of tubers from such plants are either advanced intermediate types or typical curly-dwarfs. Tubers from these degenerate plants as well as types from vigorous vines are shown in figures 10 to 13. The legends are self-explanatory. Most potato growers will agree that these degenerate tubers conform very closely to the popular notion of the ideal seed tuber. We first became convinced of such a correlation in working with the variety Howard Elliott. This name is a local one, the potato from all appearances being a typical White Elephant. Tubers of this variety are shown in figure 10. In the spring of 1915 we secured seed of this variety from the grower who introduced it under the name of Howard Elliott. This seed proved a very vigorous and productive stock, but at digging time the tubers in general had very

deep eyes. Since it proved such a heavy yielder, it was decided to continue it in the variety test plots and make an effort to select to a shallower-eyed type. Since that time seed has been selected after the digger, keeping in mind as an ideal a type similar to the second tuber from the left in figure 10. Under such selection the variety has fallen off quite noticeably in production and degenerate types of vines have become very numerous in the population. In 1918 actual counts showed more than 90 per cent of the plants with degenerate vine characteristics. The plot of this variety was dug with a fork in 1918 and without question the tuber type selected as an ideal came, in the great majority of cases, from plants showing the first signs of degeneration. In blocks of Irish Cobbler and Early Triumph, many plants of the three types have been marked and dug by hand. Here again our ideal seed type or the type we have been selecting to, came, in the great majority of cases, from the semi-curly-dwarf plant. These two varieties, as grown in the variety test plots, have been very much inclined to degeneration. Both are naturally deep-eyed types and we now feel sure that, in our eagerness to improve the type through the selection of shallow-

FIG. 16.—View in tuber-line test plot in 1918. A, semi-curly-dwarf line yielding 14,670 pounds per acre; B, advanced curly-dwarf type yielding 1,366 pounds per acre; C, normal-vigorous line yielding 31,128 pounds per acre. Variety, Green Mountain.

eyed seed tubers, we have eliminated the vigorous types and perpetuated the degenerates.

In comparing tubers from vigorous and degenerate plants, greater variation in depth of eyes will be noted on the ventral than on the dorsal surface. The ventral surface of vigorous tubers will also appear more irregular or wavy on account of the humps which develop below the eye or behind the eyebrow. This is well illustrated in figure 10. In shallow-eyed varieties, the eyebrow is more prominent on the tubers from vigorous vines than on degenerate types of tubers. In round varieties like Irish Cobbler and Early Triumph, the eye at the seed end especially will usually be found deeper on vigorous than on degenerate types of tubers. While these tuber characteristics do, in a general way, indicate the yielding power of the seed, there are exceptions to the rule and we have found no way to separate seed into vigorous and degenerate lots on tuber characteristics alone. It seems certain, however, that these characteristics are worth considering in the selection of seed potatoes from the bin or from the field after the digger.

CONCLUSIONS

Mosaic, as we have observed it, does not seem to be unlike

*F. C. Stewart. Observations on some degenerate strains of potatoes. N. Y. (Geneva) Station Bulletin 442.

curly-dwarf. From the practical viewpoint of seed improvement work, we are inclined to consider such degeneration along with curly-dwarf, accepting the yellow color as characteristic of curly-dwarf in certain varieties.

Curly-dwarf is apparently unlike other forms of degeneration we have studied in that deterioration takes place gradually. Intermediate types exist and they may be easily distinguished from normal-vigorous plants, especially when they appear in tuber unit groups. With a special seed plot method of seed production, these intermediate types may be eliminated from the population of a variety before degeneration has advanced to a point where it seriously impairs its yielding qualities.

Foliage characteristics are the most reliable indicators of degenerate tendencies. The first symptom is a slight crinkling of the foliage and as degeneration progresses there is a general reduction in vigor.

Since depth of eyes is apparently correlated with degeneration, effort to improve the type of existing varieties by the selection of shallow-eyed seed tubers should be undertaken with caution. The results of such selection work should be checked carefully with the influence upon vigor and yielding power of vines. Where seed is selected upon tuber characteristics entirely, very shallow-eyed types, especially in medium and small sizes, should be looked upon with suspicion.

In our experience all types of degeneration appear much more frequently in plots growing under unfavorable environmental conditions. We question the advisability of attempting to grow seed potatoes under conditions which do not provide sufficient moisture for maximum vine growth.

TABLE I—THREE-YEAR PERFORMANCE RECORD OF TWENTY GREEN MOUNTAIN TUBER LINES NOTED IN 1918 AS TYPICAL CURLY-DWARFS.

Yield in pounds of marketable tubers per acre.

Line Number	1916	1917	1918
307	11,615	21,836	14,402
308	6,969	27,411	11,873
312	12,195	19,513	13,938
313	9,872	25,553	13,705
314	11,034	26,482	10,840
328	10,453	15,796	10,453
334	10,453	24,623	10,221
337	12,195	15,331	7,665
341	5,807	29,269	8,595
344	1,742	9,292	489
345	15,680	14,402	1,366
346	9,292	10,685	8,001
349	8,130	23,230	12,776
364	7,549	21,836	9,292
365	10,453	23,230	11,150
368	11,034	23,230	9,808
370	10,453	16,261	7,824
374	6,388	20,442	5,342
385	5,807	21,371	4,181
402	7,549	20,907	6,504
Average of twenty lines	9,233	20,535	8,921
Average of 108 Green Mountain lines	11,335	26,595	17,493
Annual decrease in average yield of curly-dwarf lines when compared with average of entire group	2,101	6,060	8,572

TABLE II—THREE-YEAR PERFORMANCE RECORD OF NINETEEN GREEN MOUNTAIN LINES, NOTED IN 1918 AS NORMAL-VIGOROUS TYPES.

Line Number	Yield in pounds of marketable tubers per acre. 1916	1917	1918
300	10,453	20,442	26,017
317	15,099	33,915	23,472
330	9,292	27,876	30,318
332	15,099	39,026	29,424
333	14,518	37,632	25,320
338	19,164	29,269	22,738
340	13,357	28,340	24,262
348	14,518	18,584	30,715
355	14,518	22,765	20,293
362	11,615	31,592	29,966
372	13,357	30,321	31,296
377	8,516	33,849	22,997
383	12,195	35,309	22,983
390	15,099	32,522	28,362
391	16,259	30,663	32,986
394	7,549	34,380	20,674
396	7,549	36,238	25,088
400	8,130	28,590	29,269
404	15,099	34,845	22,713
Average of nineteen lines	12,704	30,850	26,257
Average of 108 Green Mountain lines	11,335	26,595	17,493
Annual increase in average yield of normal-vigorous lines when compared with average of entire group.	1,369	4,255	8,764

TABLE III—THREE-YEAR PERFORMANCE RECORD OF TWENTY-ONE EARLY SIX WEEKS TUBER LINES NOTED IN 1918 AS TYPICAL CURLY-DWARFS.

Yield in pounds of marketable tubers per acre.

Line Number	1916	1917	1918
518	10,261	21,681	8,802
520	9,872	24,004	11,247
524	13,357	21,371	13,008
527	12,357	19,977	11,150
528	11,615	22,300	12,469
538	9,292	19,977	11,615
545	6,969	17,654	7,652
547	9,292	24,624	13,473
553	10,453	14,228	14,181
555	9,292	19,745	13,936
559	8,711	17,654	17,887
566	11,034	19,745	13,203
573	9,292	15,331	15,564
576	10,453	17,190	14,402
581	13,938	22,300	16,397
582	12,776	24,452	13,241
590	10,453	23,230	16,028
592	13,938	24,623	9,524
599	11,615	25,088	10,685
613	12,195	25,088	16,137
621	8,711	16,725	4,646
Average of twenty-one lines	11,089	20,808	12,630
Average of 100 Early Six Weeks lines	12,334	24,048	17,344
Annual decrease in average yield of curly-dwarf lines when compared with average of entire group	1,245	3,240	4,714

TABLE IV.—THREE-YEAR PERFORMANCE RECORD OF FORTY EARLY SIX WEEKS TUBER LINES NOTED IN 1918 AS NORMAL-VIGOROUS TYPES

Yield in pounds of marketable tubers per acre.

Line Number	1916	1917	1918
517	15,099	20,907	19,513
519	10,453	24,159	17,654
522	12,195	28,340	19,804
526	12,776	23,230	20,293
529	13,938	26,482	18,351
532	16,261	22,997	18,584
536	8,711	25,088	18,119
540	8,711	24,159	19,977
543	12,776	18,351	22,300
548	11,034	26,017	25,320
549	13,938	25,553	24,391
551	19,745	24,623	25,553
552	17,422	25,088	25,553
554	9,872	25,553	20,907
558	12,195	26,186	20,049
560	12,776	17,422	20,538
561	9,292	20,442	29,502
562	12,776	19,978	27,873
564	11,034	23,694	19,048
565	15,680	23,229	20,907
569	15,680	16,725	20,210
571	10,453	18,816	21,139
575	10,453	21,139	19,977
577	17,422	26,017	19,513
580	15,099	23,694	21,271
584	14,518	33,683	19,071
591	12,776	24,159	20,907
594	15,099	26,548	17,654
595	12,195	30,663	21,027
600	10,453	26,017	17,654
601	7,549	27,876	19,048
604	12,195	30,810	21,516
605	14,518	29,343	20,442
607	13,938	29,966	18,584
608	11,615	30,199	22,005
609	9,292	29,734	21,516
610	11,615	27,876	16,261
618	15,099	30,663	19,048

Line Number	1916	1917	1918
620	11,034	21,518	18,119
622	12,195	26,482	19,358
Average of forty lines	12,747	25,085	20,714
Average of 100 Early Six Weeks lines	12,334	24,048	17,344
Annual increase in average yield of normal-vigorous lines when compared with average of entire group	413	1,037	3,370

Line Number	1916	1917	[illegible]
690	11,084	21,[illegible]	18,119
22	12,195	26,[illegible]	19,85[illegible]
Average of forty lines	12,74[illegible]	27,0[illegible]	21,711
Average of 100 Early Six Weeks lines	12,[illegible]	24,048	17,844
Actual increase in average yield of normal-vigorous lines when compared with average of entire group	413	1,057	3,870

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Growing and Feeding Sunflowers in Montana

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Growing Sunflowers in Montana

Alfred Atkinson J. B. Nelson

This bulletin presents a brief discussion of the characteristics and history of the cultivated sunflower and gives the results of tests on yields and methods of growing and feeding sunflowers, as carried on by the Montana Experiment Station.

THE SUNFLOWER PLANT

The sunflower plant, with its bright color, its nodding head, and large rough leaves, is very generally recognized. Botanically it is listed as *Helianthus annuus* and classified in the order Compositae. The plant is an annual, which means that it completes its life in one season.

The stem is stout, ranging from 1 to 3 inches in diameter. It varies in height from 5 to 20 feet and is usually without branches except near the top. The leaves are large and roughened and placed on the stem alternately, except near the base where they occur in pairs. The plant commonly produces from one to six heads, varying with the number of branches, and the heads range in diameter from 4 to 20 inches. The yellow ray flowers around the edge of the head vary in number from forty to eighty and these surround a center of dark brown florets. The seeds are oblong, somewhat flattened, and approach a diamond shape when cut directly across. The seed color ranges from white to dark brown, while some combine the two colors, being dark with light-colored stripes.

HISTORY

One of the best statements available on the origin and history of the sunflower was prepared by Wylie in 1901 and published in Bulletin 60 of the Bureau of Chemistry of the U. S. Department of Agriculture. This publication is the chief source from which our historic information on sunflowers is drawn.

Probably the earliest cultivation of the sunflower was carried on in Spain, about the middle of the sixteenth century. In a description published by a Flemish botanist about this time the

plant is referred to as of Peruvian origin. This belief became general because of the fact that a Spanish expedition had visited Mexico and Peru a short time prior to this date and a number of new plants had been collected in these countries and brought to Spain. Peru was probably not the original source of the sunflower, as explorers who went there later reported that the natives were not familiar with the plant.

Dr. Asa Gray, who has carefully studied the history of the sunflower, says, "Judging from the breadth of the flower heads soon after its introduction into Europe, it must, in aboriginal hands, have assumed much of the abnormal development which distinguishes the cultivated sunflower from its wild original of the western plains." One European botanist reports the results of a count made in 1671, which showed 2,362 seeds in one head. Gray's conclusions are borne out by the observations of Champlain who made explorations in the Georgian Bay district in 1615. He found the Indians there cultivating sunflowers. The seeds were used for food to some extent, and oil, made by crushing the seeds, was prized by the Indians for use on their hair.

DEVELOPMENT OF VARIETIES

Growers in Russia have been active in developing varieties of sunflowers. Vegetable oils and oily foods have an important place in the Russian diet, and this created an active demand for sunflower seeds at an early date. As early as 1830 sunflower oil was produced in commercial quantities in Russia, and important industries based on this production have been built up.

As a result of this demand, three varieties were produced and are generally grown in Russia. These are a large white-seeded sort, a variety with small dark seeds, and an intermediate variety with striped seeds. In the United States the last-mentioned variety, under the name of Mammoth Russian, is the one most commonly grown and was used in the tests reported in this bulletin.

SUNFLOWER INVESTIGATIONS IN OTHER STATES

A study of the publications of the experiment stations of the United States reveals the fact that very little work has been done with sunflowers. It also points out the further fact that practically all of the investigations reported were planned to find out the value

of the seed or of the head. Up to the present, very little work has been done to determine the value of the entire plant.

The 1896 report of the Maine Experiment Station gives the results of work by Bartlett, in which a green weight of sunflower heads of 13.5 tons and of the entire plant of 24.4 tons per acre was harvested. This author states that sunflower silage was readily eaten when fed to live stock in mixture with corn silage.

The Vermont Experiment Station reports a green weight of 5.7 tons of sunflower heads per acre in 1893. No records of the yield of the whole plant are given and the investigator states, "The stalks are shown by analysis to be too woody for use."

Some sunflower investigations were carried on by the Canadian Experiment Station and the results are presented in their report of 1893. Determinations were made to find the yield of the heads only, and the green weight reported was over 8 tons per acre.

In 1889 the Nebraska Experiment Station and in 1890 the Colorado Experiment Station carried on some work with sunflowers but no yields are reported.

The 1883 report of the New York Experiment Station gives the results of some tests in which a yield per acre of 50 bushels of sunflower seed, figuring 23 pounds to the bushel, was harvested. No report was made on forage returns.

Bulletin 91 of the Nevada Experiment Station reports a yield of 23 tons per acre of silage from Mammoth Russian sunflowers.

SUNFLOWER TESTS UNDER IRRIGATION IN MONTANA

The tests to determine yields and methods of planting conducted by the agronomy department of the Montana Experiment Station were carried on at the experiment station farm at Bozeman under irrigation. When first undertaken in 1915 the crop was planted in a small way to find out how it would react to Montana conditions. Sunflowers had not been grown as a forage crop previous to this time, so no definite set of investigations was started for the first two years. The uncertainty as to whether or not the crop was of sufficient value to merit careful investigation required that some preliminary work be carried on before definite projects on methods of growing should be worked out. In all of the tests the Mammoth Russian variety was used.

YIELDS

The crop was planted May 21, 1915, in drills 20 inches apart, using 12 pounds of seed per acre. The season was so unusually wet that it was not necessary to irrigate. The crop was cut September 29th, which was 131 days after planting. At that time the average height of the plants was 112 inches and the seeds were in the middle-dough stage. The yield per acre of the total green crop was 36.8 tons.

The results of 1915 made the crop appear so promising that sunflowers were again planted the following year. The same method of seeding as in 1915 was followed, drills 20 inches apart with 12 pounds of seed per acre. The planting was done June 6th, and the crop was irrigated July 24th. The harvesting was done September 12th, only 98 days after planting. The warm season of 1916 forced the crop much faster than the previous year. At harvesting time the crop averaged 109 inches high, and the average yield of green silage material was 31.07 tons per acre.

The large yields and obviously high quality of the sunflower crop as shown by the preliminary results of 1915 and 1916 led to the starting of some definitely planned work to test the relative returns from sunflowers planted in different ways. The results of these tests are shown in the tables and statements which follow.

METHODS OF PLANTING

Table I shows the green weight per acre of the total sunflower plant when grown in rows at varying distances apart.

The method of planting the seed for the tests reported in this table was the use of the regular grain drill, stopping up holes so as to plant the seed in rows the desired distance apart.

TABLE I.—AVERAGE RESULTS OF PLANTING IN ROWS AT DIFFERENT DISTANCES, 1917 AND 1918.

Distance between rows (inches)	Seed per acre (pounds)	Average height (inches)	Green forage per acre (tons)
8	30	101	39.8
20	12	96	32.5
24	10	93	26.7
30	8	112	33.6
36	5	112	44.1
42	4	102	23.0

It will be noted that the highest yield was from the rows 36 inches apart. This gave an average of 44.1 tons of silage material per acre. The 8-inch rows gave an average yield of 39.8 tons, but when planted in this way the crop is very hard to harvest. The stems are fine and the heavy heads cause the stalks to become badly tangled. The 30-inch row, which yielded 33.6 tons, stood third in the test.

COMPARISON OF DRILLS AND HILLS

Since corn is commonly planted in hills, it is natural to inquire as to the results to be gained from sunflowers planted in the same way. To test this some investigations were undertaken at the experiment station at Bozeman and at the Huntley substation. The results are shown in tables II and III. A study of these tables shows that the highest yield reported, 44.1 tons per acre, was from seed drilled in rows 36 inches apart. The yield standing second, 43.4 tons, was from 30-inch rows with seed planted in hills 4 inches

TABLE II.—AVERAGE RESULTS OF PLANTING IN DRILLS AND HILLS, 1917 AND 1918.

Method of planting	Seed per acre (pounds)	Average height (inches)	Green forage per acre (tons)
Rows 20 in., drilled	12	96	32.5
Rows 20 in., hills 20 in.	7	100	25.6
Rows 24 in., drilled	10	93	26.7
Rows 24 in., hills 4 in.	12	90	26.5
Rows 24 in., hills 8 in.	7	88	26.8
Rows 24 in., hills 12 in.	5	109	27.7
Rows 30 in., drilled	8	112	33.6
Rows 30 in., hills 4 in.	9	112	43.4
Rows 30 in., hills 8 in.	6	114	39.6
Rows 30 in., hills 12 in.	4	116	40.8
Rows 36 in., drilled	5	112	44.1
Rows 36 in., hills 4 in.	6	114	38.8
Rows 36 in., hills 8 in.	4	115	39.5
Rows 36 in., hills 12 in.	3	115	38.7
Rows 42 in., drilled	4	102	23.0
Rows 42 in., hills 42 in.	2	104	18.2

Seeds were planted three to the hill.

There was no difference in the length of the season of growth due to difference in method of planting.

apart. As this is very similar to straight drill planting it supports the conclusion indicated by the results shown in Table I.

The lowest yield in all tests was with seed planted in hills 42 inches apart each way. This averaged only 18.2 tons and gave very coarse stalks.

The results at the Huntley substation show rather uniform yields, with the heaviest returns from rows drilled in 20 inches apart. The 20-inch rows and 6-inch hills stand second with 33.4 tons, and the 30-inch rows drilled stand third with 32.9 tons. Later tests may show that rows should be closer in the lower valleys than at the higher altitudes.

TABLE III.—RESULTS OF PLANTING IN DRILLS AND HILLS AT THE HUNTLEY SUBSTATION,* 1918.

Method of planting	Seed per acre (pounds)	Silage per acre (tons)
Rows 20 in., drilled	24	37.6
Rows 20 in., hills 6 in	26	33.4
Rows 20 in., hills 12 in	12	32.2
Rows 30 in., drilled	16	32.9
Rows 30 in., hills 6 in	18	31.7
Rows 30 in., hills 12 in	10	31.8
Rows 40 in., drilled	12	31.0
Rows 40 in., hills 6 in	14	26.7
Rows 40 in., hills 12 in	8	26.5

*This work at the Huntley substation is carried on in cooperation between the Office of Western Investigations of the U. S. Department of Agriculture and the Montana Experiment Station.

DATES OF PLANTING

In 1918 sunflowers were planted at the experiment station at Bozeman on seven different dates at one week intervals to find the influence of the date of planting on the yield. The results of this test are shown in Table IV. All the harvesting was done October 3d as this was as late as the crop could be allowed to stand.

A study of the data shows that while the heaviest yield is from the earliest planting, there are peculiar variations in the yields as the date of planting advances. In this connection it is of interest to note the rapidity with which the plants started after the seeds were planted on the later dates. With the planting of April 29th it was

twelve days before plants were up, while with the planting of May 29th the young plants were up in five days, with the planting of June 4th in four days, and with the planting of June 10th in three days. The favorable growing conditions prevailing at the time of the later plantings made for prompt germination and very rapid growth at the start.

The results shown in the table and the observations on the growth of the crop warrant the recommendation that the planting of sunflowers in the higher altitudes, where the season is short, should be done as soon as the ground has become warm and is in good condition in the spring. All of the investigations will be continued through a series of years, so more complete information will be accumulated.

TABLE IV.—YIELD OF SUNFLOWERS PLANTED ON DIFFERENT DATES

Date of planting	Date plants appeared	Height (inches)	Silage per acre (tons)
April 29	May 11	112	39.7
May 6	May 18	102	24.8
May 13	May 24	98	21.5
May 20	May 30	96	26.6
May 29	June 3	99	36.8
June 4	June 8	86	37.2
June 10	June 13	85	22.0

The planting was done with a drill, in rows 24 inches apart, using 20 pounds of seed per acre.

SUNFLOWERS FOR DRY LAND

Some dry-land tests with sunflowers were made in 1918. These were in cooperation with the county farm bureaus and under the direction of the county agricultural agents. Over thirty acres of sunflowers were planted on thirteen different farms in eight different counties. The area planted varied from one-eighth acre up to several acres on a farm.

The average yield in these dry-land tests was 10.3 tons of silage per acre. As this was a season of unusually low precipitation, it is fair to conclude that sunflowers are promising dry-land forage producers.

SUNFLOWER SEED

Sunflower seed failed to mature three of the four years it was grown at Bozeman. A small percentage of the crop left for seed ripened in 1918 and the seed will be planted in 1919 in the hope of developing an early-maturing strain. From observations it appears that seed should mature regularly in the lower valleys where the temperature is higher and the frost-free period longer.

PLANTING RECOMMENDATIONS

In the light of four years' experience in growing sunflowers, it has been found that the most practical way of planting the seed is with the ordinary grain drill. A sufficient number of the feed outlets should be stopped up to permit of planting only in rows 30 to 36 inches apart. The drill should be regulated so that the seeds will be dropped 4 to 5 inches apart in the row. The set for this will vary with different drills, but with a standard Van Brunt the desired distribution may be secured when the drill is set to plant 4 pecks of wheat to the acre. Planting in this way, rows 36 inches apart and seeds 4 to 5 inches apart in the row, will require 5 pounds of seed to the acre on the average. The prevailing price has been close to 15 cents a pound, which means a total outlay for seed of 75 cents per acre.

SUMMARY

1. The sunflower plant was early grown in Spain, but the best information available points to the fact that it was first grown and much improved by the Indians of North America.

2. The early commercial importance of the sunflower in Russia led to the development of three special varieties in that country. These are a large white-seeded sort, a variety with small black seeds, and an intermediate variety with striped seeds. The last-mentioned variety under the name Mammoth Russian is the one commonly grown in the United States.

3. Comparatively little work has been done by the experiment stations of the United States on the yield and value of the entire sunflower plant for forage. The Maine Experiment Station reports a yield of 24.4 tons and the Nevada Experiment Station a yield of 23 tons of silage per acre.

4. Tests with sunflowers have been carried on by the Montana Experiment Station for four years, 1915 to 1918 inclusive. The tests

in 1915 and 1916 were preliminary, to find the yield of the crop. This was 36.8 tons in 1915 and 31.07 tons in 1916.

5. Method and date-of-planting tests were conducted in 1917 and 1918 at the experiment station at Bozeman and at the Huntley substation.

6. A comparison of yields, after planting in rows at different distances apart, showed the largest returns, 44.1 tons per acre, with rows 36 inches apart.

7. A comparison of planting in drills and hills at varying distances apart, at the station at Bozeman, showed that the highest yields were harvested when the crop was planted in drills from 30 to 36 inches apart.

8. The highest yield at the Huntley substation was from rows 20 inches apart.

9. In date-of-seeding tests at the Bozeman station the largest yields were produced from the earliest plantings.

10. In dry-land tests, conducted in eight different counties, the average yield of sunflower silage was 10.3 tons per acre.

11. Sunflower seed matured only one out of the four years at the Bozeman station. It is expected, however, that it will mature regularly in the lower valleys.

12. Planting is best done with the ordinary grain drill set for rows 30 to 36 inches apart and adjusted to drop seeds 4 to 5 inches apart in the row.

Feeding Sunflowers

C. N. Arnett W. E. Joseph Oscar Tretsven

Mammoth Russian sunflowers have been grown and used for both soiling and silage purposes with entirely satisfactory results at the Montana Experiment Station for the past four years.

The value of corn silage as a feed for beef cattle, dairy cattle, and sheep has long been established. Corn can be grown very satisfactorily in some sections of Montana for silage purposes while in other sections the season is too short, nights too cool, or the rainfall inadequate to produce sufficient tonnage or to properly mature corn for silage. Realizing that silage corn could not be profitably or economically produced in many sections of the state, the department of animal husbandry has tested various crops, such as medium red clover, alfalfa, oats, corn, and Mammoth Russian sunflowers for silage purposes. The practical and experimental results to date, when feeding qualities, yields per acre, and frost-resisting qualities are considered, are greatly in favor of the sunflowers. Sunflowers have withstood a temperature of 27° F. on the experiment station farm with practically no effect. In fact, the results with the sunflower plant when used for both soiling and silage have been so satisfactory that all practical work with the other crops has been discontinued.

HOW SUNFLOWER SILAGE MAY BE USED

Sunflower silage may be used as a winter feed for practically all classes of farm stock. This station has successfully used it in winter feeding beef calves, dairy cows, breeding beef and dairy bulls, breeding ewes, and to a limited extent with brood sows. To date all the feeding experiments have been conducted during the winter months but there is no reason why sunflower silage could not be used to good advantage on many farms to supplement pastures in dry seasons or when they become inadequate in the fall.

Feed is one of the best insurance policies stockmen can carry. Many farmers, especially those depending entirely upon dry-land farming, have frequently been forced to sell their stock or purchase

roughage at abnormally high prices. The silo should be part of the farm equipment on a large percentage of the Montana farms. It would be not only good insurance but good business for many farmers in the state to have two silos, and one of these should be used to carry feed through the winter for summer feeding or for feeding the following winter if crops are light, as is the case in very dry years. Silage will keep for several years if properly packed in a good tight silo.

With our present information we would not advise the use of sunflower silage as the only feed for any kind of live stock. It is usually fed in connection with dry roughage. In all feeding experiments conducted at this station either clover, alfalfa, or mixed hay has been fed with the sunflower silage. However, in digestion trials for one period of thirty days the animals used in the experiments were fed on sunflower silage only with no apparent harmful results.

PALATABILITY OF SUNFLOWER SILAGE

No difficulty has been experienced in getting cattle or sheep to eat sunflower silage. Some animals require a few days to become accustomed to it while others eat it readily from the first time it is offered. After once becoming accustomed to it, cattle take it at once when offered in subsequent seasons.

COMPOSITION OF SUNFLOWER SILAGE

Experiments were conducted as early as 1896 at the Maine Experiment Station with sunflowers as a forage crop with fairly satisfactory results but the general consensus of opinion has been that the sunflower plant is too woody (high in crude fiber) to be of value as a stock feed. Experiments at this station have completely disproved this idea. In order to secure data on the chemical composition of sunflower silage the department of chemistry of the experiment station cooperated with the department of animal husbandry in all feeding and digestion trials.

The chemical analysis of sunflower silage is as follows (average of four samples taken at different depths in the silo).

Dry substance	Crude protein	Crude fiber	Nitrogen-free extract	Ether extract	Ash
21.4	2.1	6.8	10.4	0.5	1.6

DIGESTIBLE NUTRIENTS IN
ONE HUNDRED POUNDS OF SUNFLOWER SILAGE

The foregoing chemical analysis does not give the nutritive value of the feed. To determine the digestibility of sunflower silage the departments of animal husbandry and of chemistry conducted an exhaustive digestion experiment. This work was in charge of Drs. Joseph and Blish of the respective departments. The complete data of this experiment will be published elsewhere .

The digestible nutrients as determined in these trials are given below.

	Total dry substance	Crude protein	Crude fiber and nitrogen-free extract	Ether extract	Nutritive ratio
Digestible nutrients in 100 lbs. of sunflower silage	21.4	1.24	10.13	0.37	9.8
Digestible nutrients in 100 lbs. silage from well-matured corn*	26.3	1.1	15.00	.70	15.1
Digestible nutrients in 100 lbs. silage from immature corn*	21.0	1.0	11.40	.40	12.3

*Henry-Morrison, Feeds and Feeding.

These figures show that 100 pounds of sunflower silage made from plants 5 per cent in bloom, compared with a like amount of silage made from immature corn, contains approximately the same total dry substance, that the sunflower silage is 0.24 pound higher in digestible crude protein, that there are but 1.27 pounds more digestible crude fiber and nitrogen-free extract in the corn silage, and that the ether extract is practically the same. The proportion of digestible crude protein to digestible carbohydrates in the sunflower silage is 1:9.8 while in the corn silage it is but 1:12.3. One hundred pounds of silage made from mature corn contains 4.9 pounds more total dry substance, 0.14 pound less digestible crude protein, 4.87 pounds more digestible crude fiber and nitrogen-free extract, and 0.33 pound more digestible ether extract. The proportion of protein to carbohydrates in the mature corn silage is

1:15.1 while in the sunflower silage it is 1:9.8. With low protein feeds the higher digestible crude protein of the sunflower silage would give it an advantage over the corn silage. Results from feeding experiments with sunflower silage indicate that more mature plants make a silage with a higher nutritive value but the best stage of maturity for cutting the crop we do not yet know. As practically all corn grown in the higher altitudes of Montana would have to be ensiled when immature, these figures should be used for comparison. When digestible nutrients, yield per acre, drought and frost-resisting qualities of the sunflower are compared with corn, it is readily seen that sunflowers have a distinct advantage over corn for silage purposes in the higher mountain valleys of the West or in other sections of the United States or Canada with similar climatic conditions.

SUNFLOWER SILAGE FOR DAIRY CATTLE

The first and preliminary experiment to determine the value of sunflower silage for feeding dairy cows was conducted in 1915. The amount of silage available for this work was limited and the only practical and valuable conclusions from this preliminary work were to establish the facts that dairy cows would eat sunflower silage readily, that there was no diminution in their milk flow when part of their ration was composed of sunflower silage, and that there was no apparent change in the odor and flavor of milk from cows when fed on such forage. This work paved the way for more exhaustive and comprehensive experiments.

RELATIVE VALUE OF SUNFLOWER SILAGE AND CLOVER HAY FOR DAIRY COWS—EXPERIMENTS 1916-17

The sunflowers during the season of 1916 were harvested and ensiled when only about 5 per cent of the plants were in bloom. They yielded under field conditions with limited subirrigation only 22 tons per acre on a 3-acre field. Corn grown under exactly the same conditions yielded only 5 tons.

To determine the feeding value of the sunflower silage two lots of cows were fed. Each lot contained seven cows as nearly equal as possible in breed, age, weight, condition, period of lactation, pregnancy, milk production, and fat test. Lot I received grain and clover hay and Lot II, grain, clover hay, and sunflower silage. The grain fed was a mixture of oats, 5 parts; malt sprouts, 2 parts; and

bran, 3 parts. The clover used was choice alsike. At the end of twenty-eight days the lots were reversed and Lot I was fed grain, clover hay, and sunflower silage, and Lot II, grain and clover hay for twenty-eight days. This change was made to eliminate as far as possible variations due to individuality among the cows. A preliminary feeding period of seven days was given at the beginning of each period of the experiment in order to accustom the animals to the change in feed. Individual weights were taken three days at the beginning and again at the close of each period, and the averages of these weighings were taken as the initial and final weights. Individual records of milk produced and fat tests were used in order to determine the production.

To simplify the discussion of results, the data obtained from Lot I and Lot II while fed grain and clover hay are combined in one column of Table V. Likewise, the data obtained from lots I and II while fed grain, clover hay, and sunflower silage are combined.

Table V gives a brief summary of the entire experiment. The figures show that the fourteen cows, while receiving the ration of grain and clover hay, gained on the average 5 pounds more per head in twenty-eight days than while they received the ration containing sunflower ensilage. The grain ration was the same through-

TABLE V.—SUMMARY OF EXPERIMENT ON RELATIVE VALUE OF SUNFLOWER SILAGE AND CLOVER HAY FOR DAIRY COWS

		Lot I	Lot II
		Grain and clover hay	Grain, clover hay and sunflower silage
Number of cows in each lot		14	14
Number of days in test		28	28
Average initial weight	(lbs.)	1072	1081
Average final weight	”	1083	1087
Average gain for period	”	11	6
Average daily ration			
Grain per head daily	”	13	13
Clover hay per head daily	”	21	12
Sunflower silage per head daily	”	....	34
Average daily milk per cow	”	33.37	34.35
Average daily butter-fat per cow	”	1.382	1.459

out the entire experiment and an average daily feed of 34 pounds of sunflower silage effected a daily saving of 9 pounds of clover hay per cow. There was a slight increase in production while the cows were receiving the sunflower silage. This increase amounted to 0.98 of a pound of milk and 0.77 of a pound of butter-fat daily. This difference was too small to be of significance except as indicating that there was no reduction in milk or butter-fat production due to the feeding of sunflower silage in place of a part of the clover hay in the ration. The data presented indicate that under the conditions of this experiment 1 pound of choice alsike clover hay is equal to 3¾ pounds of sunflower silage, or on the basis of average composition as obtained at this station* 0.94 pound of dry substance of sunflower silage was equivalent to 1 pound of dry substance of choice alsike clover hay under the conditions of this experiment.

The milk from cows fed sunflower silage was sampled and tested for flavor but no objectionable flavors or change in the milk could be detected.

RELATIVE VALUE OF SUNFLOWER SILAGE AND ALFALFA HAY EXPERIMENTS 1917-18

The silage used in the 1917-18 experiments was made from Mammoth Russian sunflowers that were approximately 30 per cent in bloom. They were harvested between the 13th and 20th of September and yielded 24 tons per acre with limited subirrigation only. In this experiment sunflower silage was compared with choice alfalfa hay. Sixteen cows were divided into two equal lots; size, type, stages of lactation and gestation, and the amount and richness of the milk were considered in making the division.

The plan for the feeding was to give each lot of cows the same amount of grain, though each individual cow was to be fed according to her production of milk—1 pound of grain to 3 pounds of milk produced. On account of a few cows going off feed it was necessary to make a slight deviation from this rule. The grain ration for both lots consisted of a mixture of 4 parts of rolled oats, 4 parts dried beet pulp, and 2 parts cottonseed meal. For roughage one lot was fed all the choice alfalfa hay the animals would consume

*Dry substance in clover hay, about 85 per cent; in sunflower silage, 21.38 per cent.

and the other lot received all the sunflower silage they would readily eat and a small allowance of alfalfa hay.

Seven days' preliminary feeding was given to each lot to accustom the cows to their changed rations. The first period of the experiment covered thirty-three days. At the end of this period the two lots were interchanged; seven days were taken in making the transition from one ration to the other. The second period of the test continued for thirty-five days. The object of interchanging the lots was to eliminate any difference due to individuality of the cows.

Table VI gives a summary of results. This shows that Lot I received slightly more grain than Lot II. The lot receiving alfalfa only ate on the average 26.65 pounds of alfalfa hay and the lot receiving sunflower silage ate on the average 10.93 pounds of alfalfa hay and 41.26 pounds of sunflower silage. Thus 15.72 pounds of alfalfa hay was replaced by 41.26 pounds of sunflower silage, a ratio of 1 pound of hay to 2.63 pounds of silage. Under the conditions of this experiment 2.62 pounds of sunflower silage were not quite equal to 1 pound of alfalfa hay, as the results show that the cows in Lot I gained 5.3 pounds more in live weight and produced 0.84 pound more milk per cow daily. The butter-fat production was approximately the same. Allowing for the difference in gains in live weight and milk produced, it was found that 2.83 pounds of sunflower silage were

TABLE VI.—SUMMARY OF EXPERIMENT ON RELATIVE VALUE OF SUNFLOWER SILAGE AND ALFALFA HAY.

		Lot I	Lot II
		Grain and alfalfa hay	Grain, alfalfa hay, and sunflower silage
Number of cows in each lot		16	16
Number of days in test		34	34
Average initial weight	(lbs.)	1174.2	1196.8
Average final weight	"	1188.0	1205.1
Average gain in weight	"	13.8	8.3
Average daily ration			
Grain per head daily	"	10.53	10.46
Alfalfa hay per head daily	"	26.65	10.93
Sunflower silage per head daily	"	....	41.26
Average daily milk per cow	"	29.01	28.17
Average daily butter-fat per cow	"	1.13	1.12

equal in feeding value to 1 pound of good alfalfa hay under the conditions of this experiment. Under the same conditions 0.71 pound of dry substance of sunflower silage was equivalent to 1 pound of dry substance in alfalfa hay.*

SILAGE FROM EARLY-CUT vs. LATE-CUT SUNFLOWERS
EXPERIMENTS 1918-19

It is important to determine the proper stage of maturity for harvesting sunflowers to obtain the maximum quantity of palatable silage. The bloom is the best factor to indicate the stage of maturity. This initial experiment was limited to two stages of maturity; first, 30 per cent of the plants in bloom, and second, 90 per cent in bloom when the crop was harvested. The first stage will be referred to in this discussion as early-cut and the second as late-cut silage. The silage was stored in separate silos and fed at the same time in direct comparison.

Two lots of eight dairy cows each were used in this experiment. The lots were as nearly equal as possible when all factors were

TABLE VII.—SUMMARY OF EXPERIMENT COMPARING SILAGE FROM EARLY-CUT AND LATE-CUT SUNFLOWERS

		Early-cut silage	Late-cut silage
Number of cows in each lot		16	16
Number of days in test		28	28
Average initial weight	(lbs.)	1205.8	1211.3
Average final weight	”	1218.2	1218.1
Average gain for period	”	12.4	6.8
Average daily ration			
Grain per head daily	”	11.65	11.50
Hay per head daily	”	14.0	13.9
Silage per head daily	”	41.0	40.3
Average daily milk per cow	”	30.28	31.03
Average daily butter-fat per cow	”	.995	1.02

considered. Initial and final weights are the average of three successive daily weights; accurate records were kept of milk and fat production. The grain mixture fed during the first period consisted of 8 parts oats, 1 part barley, and 1 part wheat bran. During the

*Amount of dry substance used in calculating these results—alfalfa hay, 85 per cent, and sunflowers, 21.38 per cent.

first half of the second period the grain was the same as for the first period. It was then changed to 6 parts oats, 1 part barley, and 3 parts bran. The hay fed was red clover of average quality. The feeding was so planned that the two lots of cows would receive exactly the same amounts of grain, hay, and silage. As the grain and hay for the two lots were of the same kind and grade, any difference in production, gain or loss in live weight could be attributed to the difference in feeding value of the silage. A preliminary feeding period of seven days was given each lot to accustom the cows to the change in their ration. At the end of the twenty-eighth day the lots were changed so that during the experiment each cow had twenty-eight days' feeding on each of the two different silages. Seven days were allowed for the transitional period when changing from one silage to the other. Table VII presents the summary of the experiment. In order to simplify the discussion the two lots are combined so the figures show sixteen cows were fed twenty-eight days on early-cut silage and sixteen cows for twenty-eight days on late-cut silage.

The data presented show the cows when receiving the early-cut silage averaged a gain of 5.6 pounds more in live weight during the twenty-eight days and consumed on an average 0.15 pound more grain, 0.11 pound more hay, and 0.7 pound more silage per head per day than during the period they were fed the late-cut silage. During the period they received the late-cut silage they produced 0.75 pound more milk containing 0.025 pound more butter-fat per day per cow than when fed the early-cut silage.

The greater average gain in live weight while the cows were fed the early-cut silage may be due to the fact that the grain and hay during this period were slightly more than when they were fed the late-cut silage. On the other hand, the cows produced slightly more milk and butter-fat while fed on the late-cut silage. It is impossible to draw definite and guiding conclusions as to the proper stage of maturity for cutting sunflowers from this one experiment. Additional experiments on this problem are in progress at present.

SUNFLOWERS AS A SOILING CROP FOR DAIRY COWS

Green sunflowers have been used very successfully as a soiling feed for dairy cows in the late summer as a supplement to pasture and also as the only green feed fed. They have the advantage over

most other crops that can be grown for soiling purposes in that they can be fed through a longer period of time.

SUNFLOWERS vs. GREEN CORN

Green sunflowers and green corn were compared as supplements to the pasture during the latter part of the grazing season. Both were run through a feed cutter and chopped into one-inch lengths. Only 5 per cent of the sunflowers were in bloom and the corn was in the silk stage. The cows ate the green sunflowers readily, consuming from 40 to 90 pounds per head daily, kept up their milk flow, and apparently did well on the feed. Results of this test indicated that under the conditions of this experiment the sunflowers and corn were of equal feeding value.

In the second experiment to study the relative value of sunflowers and green corn, two lots of six cows each were used. The cows were divided as equally as possible when weight, age, period of lactation, and production were considered. Both lots had access to a small pasture and received the same grain ration. The cows in Lot I were fed all the chopped sunflowers they would eat while those in Lot II were fed all the chopped green corn they would eat. At the time the test closed the corn was in the roasting-ear stage and the sunflowers were about 40 per cent in bloom. Table VIII gives the results of this experiment.

One cow in Lot II went off feed, thus making a slight difference in the amount of grain and soiling crop consumed and no doubt slightly affecting the production. In all probability the increase in production and decrease in loss of live weight in favor

TABLE VIII.—SUMMARY OF EXPERIMENT COMPARING SUNFLOWER SILAGE AND GREEN CORN

		Sunflowers	Corn
Number of cows in each lot		6	6
Number of days in test		28	28
Average initial weight	(lbs.)	1119.5	1112.7
Average final weight	”	1111.7	1092.3
Loss in live weight per cow	”	7.8	20.4
Average grain fed per cow daily	”	8.71	8.55
Average soiling crop fed per cow daily	”	64.5	62.6
Average milk produced per cow daily	”	39.39	38.106
Average daily butter-fat per cow	”	1.406	1.375

of sunflowers would offset the difference in feed consumed. The conclusions from this experiment are that under the conditions of this test chopped green sunflowers and chopped green corn gave equal results as a soiling crop for dairy cows. These results substantiate the conclusions from the preliminary test reported.

SUNFLOWER SILAGE FOR BEEF CATTLE

Sunflower silage has been fed to beef cattle of practically all sizes and ages. It has been used to a limited extent for feeding pure-bred beef calves before weaning. No records were kept of the weights of feed and the gains of the calves but they appeared to do very well on it. Grade beef calves have also been fed rations containing silage as half or more of the roughage of the ration with favorable results. Two-year-old steers were fed a limited ration of sunflower silage only for a period of thirty days with satisfactory results. Mature pure-bred beef cows have been fed silage as the morning feed and hay as the evening feed with good results. The experimental data on feeding silage to beef cattle are too limited to attempt to assign to it a definite value in such rations. Enough feeding work has been done to indicate that it is well adapted for this purpose. It has been found that calves can be put on a heavy feed of silage too rapidly. Under this condition they have gone off feed with the result that it was very difficult to bring them back to a heavy feed of silage again during that season. No difficulty of this kind has been experienced with mature stock.

SUNFLOWER SILAGE FOR BREEDING EWES

During the winter of 1917-18 a short test was conducted to determine the feeding value of sunflower silage for breeding ewes. Ordinarily hay makes up a considerable part of the ration of breeding ewes before lambing. This feeding test was planned, therefore, with the object of determining the value of sunflower silage in replacing a part of the hay of the ration.

Each lot of ewes was made up of ten pure-bred Rambouillets and five pure-bred Shropshires. They were in good condition at the beginning of this test.

Lot I was fed a ration of alfalfa which would grade as good hay until about twenty days before the lambing season began when a small amount of oats was fed in addition. Lot II was fed approximately 1 pound less hay per head daily and as a substitute

about 2.2 pounds of sunflower silage which was made from Mammoth Russian sunflowers when about 30 per cent in bloom. Lot II was fed the same amount of oats as Lot I, but owing to the fact that the ewes of Lot II lambed a little earlier than those of Lot I the period during which oats were fed was not quite as long. For this reason the daily allowance of oats when averaged for the entire test was somewhat less for Lot II.

These feeds were so fed that there would be a minimum of waste or refused feed. From the hay there was a little residue which consisted mainly of stubble and other foreign substances. There was also a very small amount of silage that was not cleaned up which amounted to but 1 or 2 per cent of the amount fed. These residues were weighed back and the amounts deducted from the amount fed.

In Table IX are given the results of this test. The length of the test was seventy-seven days for Lot I and seventy-four days for Lot II. The average initial weight per head in Lot I was 167 pounds and in Lot II, 164 pounds. The ewes were of fairly large size and would therefore require a little more feed for maintenance than the average ewe.

TABLE IX.—SUMMARY OF EXPERIMENT ON WINTERING BREEDING EWES. DATA ON EWES BEFORE LAMBING.

		Alfalfa	Sunflowers
Number of ewes in lot		15	15
Average number of days on feed before lambing		77	74
Initial weight of lot	(lbs.)	2498	2461
Final weight of lot	”	2696	2647
Average initial weight per ewe	”	167	164
Average final weight per ewe	”	180	176
Total gain by lot	”	198	186
Average gain per ewe	”	13.2	12.4
Total feed consumed by the lot			
Alfalfa hay	”	4490.3	3332.5
Sunflower silage	”	....	2429.7
Oats	”	236.0	184.4
Average daily ration			
Alfalfa hay	”	3.89	2.99
Sunflower silage	”	....	2.18
Oats	”	.20	.17

The gains were 13.2 and 12.4 pounds respectively. While these gains were not enough to cover losses in weight at lambing time, they were considered ample in this case, owing to the fact that the ewes were in good condition at the beginning of the test.

The hay of the rations varied 0.9 pound. As a substitute for this amount of hay 2.18 pounds of sunflower silage was fed to Lot II. The ratio of hay to silage in these rations was 1:2.4. The gains were somewhat less in the lot fed silage, but the amount of oats fed was also somewhat less in this lot. The additional gains in Lot I were only very slightly more than can be accounted for by the additional amount of oats fed. The results of this test indicate that for ewes before lambing 2.5 pounds of this silage is equivalent to 1 pound of good alfalfa hay.

The silage was also fed after lambing, but owing to the increasing number of variables the results are not as clear-cut as before lambing. Loss of lambs, differences in number of twins, differences in the milking qualities of the ewes, and the shorter feeding period are causes of greater variability. Such results as were obtained indicate that the feeding value of the sunflower silage was not as great relative to the feeding value of hay as before lambing. The amount of silage was increased to practically 3 pounds per head daily after lambing.

No unfavorable results were obtained from feeding the silage to breeding ewes either before, during, or after lambing. Sunflower silage proved to be a valuable substitute for a part of the hay in a ration for breeding ewes before lambing. While the results obtained after lambing were not so definite, its addition at this time gave fair results.

SUNFLOWER SILAGE FOR BROOD SOWS

As a preliminary test sunflower silage was compared with alfalfa hay in rations for brood sows. The grain ration was practically the same for the two lots. A small amount of skim-milk was fed also. While the results are only tentative it was found that brood sows would eat sunflower silage readily. During a part of the feeding period they ate four pounds per head daily in addition to the small amount of skim-milk and the grain required to maintain the dry sows. The silage was first fed about two months before the farrowing season began and it was fed through the farrowing season and for a period of about four weeks thereafter with no

unfavorable results. While roughage of this character does not replace a very large part of the grain of the ration, it serves an excellent purpose in keeping the sows in splendid condition, being as satisfactory in this respect as alfalfa hay. In this trial it appeared that 2.5 pounds of silage were at least equivalent in feeding value to 1 pound of hay.

TIME TO CUT SUNFLOWERS FOR SILAGE

Good silage can be made from Mammoth Russian sunflowers from the time they begin to bloom until the seeds begin to harden. The stage of growth that will produce the maximum weight of the most palatable and digestible silage has not yet been determined. Apparently there is a greater loss of juices when the crop is harvested in the immature stage. In the feeding experiments so far conducted the 1917-18 silage shows a greater feeding value than that used in the 1916-17 experiment. This is probably due to the fact that the plants were more mature in 1917-18 when the crop was harvested. Results from the experiment comparing silage from sunflowers that were 30 per cent and 90 per cent in bloom were inconclusive. Unless frost or dry weather stops growth, the sunflowers should not be harvested before they are at least 50 to 60 per cent in bloom. Further experimental work may show that more mature plants make silage of a higher feeding value. The depart-

FIG. 1.—The corn binder is the most satisfactory method of harvesting sunflowers.

ment has a very complete series of tests in progress at present to determine this point.

FIG. 2.—Hand-cutting is slow and expensive but necessary if the sunflowers have lodged and become tangled.

FIG. 3.—When sunflowers are firmly rooted and standing, the sled with a stationary knife attached to one side can be used for cutting.

FIG. 4.—Low, flat-topped wagons are desirable for hauling sunflowers to the silo.

METHOD OF CUTTING SUNFLOWERS

Sunflowers have been harvested by hand, with a sled cutter, and with a corn binder. The corn binder is decidedly the most satisfactory method. Practically no difficulty was experienced in cutting sunflowers that were 8 to 10 feet in height. When the stalks were very tall they tangled more or less, owing to the heavy heads. When the crop lodges and becomes tangled because of high winds or early wet snows, hand cutters are the most satisfactory. Harvesting by hand is slow and expensive with present labor costs. The sled with a stationary knife attached to one side can be used when the plants are firmly rooted and standing. This method is slightly faster and cheaper than harvesting by hand.

FILLING THE SILO

Low, flat-topped wagons are desirable for hauling the sunflowers from the field to the silo. The ordinary corn silage cutter is used in cutting and filling the silo. A cutter with rather wide throat will handle the heads more readily. More power is generally required than for cutting corn. At least two men should be in a 16-foot silo to thoroughly pack the silage.

SUMMARY

1. Mammoth Russian sunflowers have been successfully and satisfactorily used for both soiling and silage purposes for the past four years at the Montana Experiment Station.

2. Sunflower silage, made from plants that are 30 per cent in bloom, compares favorably in total digestible nutrients with corn silage made from immature corn.

3. Little difficulty has been experienced in getting stock to eat sunflower silage. In some cases a few days have been required to get them to eat it readily. It is palatable to cattle, sheep, and swine.

4. No objectionable flavors or odors could be detected in milk from cows fed green sunflowers or sunflower silage.

5. In the experiment of 1916-17, 3.75 pounds of sunflower silage was equal to 1 pound of choice alsike clover hay when fed to dairy cows receiving grain and a limited hay ration.

6. In the experiment of 1917-18, 2.83 pounds of sunflower silage was equal to 1 pound of alfalfa hay when fed to dairy cows receiving grain and a limited hay ration.

7. Chopped green sunflowers 30 to 40 per cent in bloom were equal to chopped green corn in the roasting-ear stage as a soiling crop for dairy cows.

8. Sunflower silage is a valuable substitute for a part of the hay in a ration for breeding ewes, 2.5 pounds of sunflower silage replacing 1 pound of alfalfa hay in such a ration in an entirely satisfactory manner.

9. Brood sows ate sunflower silage readily, 2.5 pounds of silage being apparently as high in feeding value as 1 pound of choice alfalfa hay when fed as a supplement to a grain ration.

10. Experimental work to date indicates that silage made from plants that are 30 per cent in bloom has a higher feeding value than silage made from plants that are less mature.

11. The exact stage of growth that will give the highest quality of silage has not yet been determined.

12. The most practical method of harvesting sunflowers is with the ordinary corn binder.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

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Corn Experiments at the Judith Basin Substation

Corn grown at Judith Basin Substation, 1918. This plot yielded at the rate of 8000 pounds of field-cured fodder to the acre, an equivalent of at least ten tons of silage. The ten-year average yield of corn at this station has been about 5000 pounds to the acre.

BY

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Judith Basin Substation

Corn Experiments at the Judith Basin Substation

That corn should find an important place in the cropping systems of a region lying 4300 feet above sea level at 47 degrees north latitude is as surprising as it is interesting, especially in view of the fact that it must be grown, for the most part, without irrigation, and the average annual precipitation for the last ten years*, as shown in Table I, is only 18.06 inches, of which an average of 50 per cent or but 10.6 inches falls during the growing season. Moreover, it is upon the rainfall of the growing season that the crop is almost wholly dependent, for the soil of this region is of such a character as to make a large storage of excess precipitation quite impossible. The surface soil itself, being a rather dark, heavy clay-loam, is effective enough in the retention of moisture up to the point of saturation; but it is relatively shallow, varying in depth from a few inches to about four feet, and is underlaid with a lime gravel, closely cemented by calcareous substances. Under these conditions the crop must mainly depend for its moisture on that retained by the shallow surface soil. Fortunately few of the storms occurring during

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The experimental results reported in this bulletin are based on studies made under a cooperative arrangement between the Montana Agriculutral Experiment Station, Bozeman, and the Office of Dry-Land Agriculture, Bureau of Plant Industry, United States Department of Agriculture.

The Judith Basin is in Fergus County and comprises an area of approximately two million acres of tillable land, most of which is now being farmed. The Basin is drained by the Judith River and is nearly surrounded by mountains. The greater part of this area consists of gently rolling or nearly level bench lands and is not irrigated. A comparatively small amount of land along the creek bottoms has been under irrigation since the first settlers of this region located there.

The Judith Basin Substation is located two miles west of the town of Moccasin, which lies almost in the geopraphical center of the state. The substation is conducted cooperatively by the Montana Agricultural Experiment Station and the Bureau of Plant Industry, United States Department of Agriculture.

*Weather records have been kept at the Judith Basin Substation since its establishment, the necessary equipment being supplied by the Office of Biophysical Investigations of the Bureau of Plant Industry, U. S. Dept. of Agriculture.

the growing season bring more moisture than the surface soil can hold, and hence the crops are able to utilize a very high percentage of the rainfall.

Another factor which enhances the value of this equable distribution of rainfall is the relatively low evaporation, as shown in Table II. Owing to this low rate of evaporation, much more of the moisture that falls can be made use of by the plants than is the case farther south where the rate of evaporation is higher. While

TABLE I.—MONTHLY PRECIPITATION DURING THE GROWING SEASON, SEASONAL PRECIPITATION, AND ANNUAL PRECIPITATION AT THE JUDITH BASIN SUBSTATION FOR THE YEARS 1909 TO 1918, INCLUSIVE.

Year	Apr.	May	June	July	Aug.	Sept.	Seasonal	Annual	Percentage of seasonal to total
1909	1.03	1.34	5.99	2.54	4.21	4.47	15.11	23.78	64
1910	1.31	2.40	1.69	1.10	2.02	2.54	8.52	15.09	56
1911	1.66	2.98	2.55	.50	6.34	1.37	14.03	21.45	65
1912	1.43	3.94	.64	1.92	1.27	1.63	9.20	15.00	61
1913	.79	2.64	4.77	1.12	.51	1.01	9.83	14.96	66
1914	1.19	2.91	4.64	.64	.65	1.11	10.03	15.67	64
1915	1.43	2.12	3.97	3.54	.92	2.65	11.98	20.68	58
1916	1.20	2.25	3.97	2.03	1.29	1.81	10.74	19.87	54
1917	1.18	2.79	1.81	.96	.75	2.91	7.49	17.69	42
1918	.44	2.69	1.55	2.95	1.48	1.25	9.11	16.36	56
Avg.	1.17	2.61	3.16	1.73	1.94	2.08	10.60	18.06	59

TABLE II.—MONTHLY EVAPORATION DURING THE GROWING SEASON AT THE JUDITH BASIN SUBSTATION FOR THE YEARS 1908 TO 1918, INCLUSIVE.

Year	April	May	June	July	Aug.	Sept.	Total	Total rainfall	Ratio of precipitation to evaporation
1909	3.00	4.66	6.00	7.22	7.06	4.67	32.61	19.58	1:1.6
1910	5.18	5.61	7.21	8.28	7.38	6.48	40.14	11.06	1:3.6
1911	4.10	5.94	5.13	7.31	6.35	3.41	32.24	15.40	1:2.1
1912	2.62	4.14	6.39	5.97	6.23	3.42	28.77	10.83	1:2.6
1913	3.89	4.23	4.90	6.37	7.35	5.58	32.32	10.84	1:3.0
1914	3.21	4.85	4.43	7.45	7.24	5.10	32.28	11.14	1:2.8
1915	4.70	4.61	4.35	4.89	6.51	3.44	28.50	14.63	1:1.9
1916	5.35	5.26	5.62	6.89	7.57	4.84	35.53	12.55	1:2.8
1917	2.47	5.06	6.06	9.58	7.87	4.64	35.68	10.40	1:3.3
1918	3.87	4.22	6.76	5.77	5.65	3.43	29.70	10.36	1:2.9
Avg.	3.84	4.86	5.69	6.97	6.92	4.50	32.78	12.68	1:2.6
Avg. rainfall	1.17	2.61	3.16	1.73	1.94	2.08		12.68	

the rate of evaporation in the Judith Basin is higher during July and August than in any other month, it probably is considerably lower than it would be were it not for the fact that there is generally comparatively little wind during those two months, as the records presented in Table III show.

TABLE III.—AVERAGE WIND VELOCITY IN MILES PER HOUR AT THE JUDITH BASIN SUBSTATION, BY MONTHS FROM APRIL TO SEPTEMBER, FOR THE YEARS 1910 TO 1918, INCLUSIVE.

Year	April	May	June	July	August	Sept.	Avg.
1910	9.0	6.8	6.3	5.9	6.0	4.0	6.33
1911	7.8	8.0	5.4	5.9	5.9	5.3	6.38
1912	6.6	7.6	5.7	5.1	6.4	6.7	6.35
1913	8.7	6.5	5.3	5.0	5.4	6.5	6.23
1914	6.3	7.5	6.4	5.5	6.0	7.2	6.48
1915	7.6	7.5	6.6	5.1	4.9	5.9	6.27
1916	8.1	9.2	7.7	5.6	5.3	6.9	7.13
1917	7.8	7.6	7.4	5.9	6.1	7.1	6.98
1918	8.9	6.8	6.0	4.5	4.9	4.9	6.00
Avg.	7.87	7.50	6.31	5.39	5.66	6.06	6.46

The water requirements of the crops are also of considerable importance in a district of low rainfall. Experiments carried on by Briggs and Shantz, of the U. S. Department of Agriculture, show that considerably less water is required to produce a pound of dry matter in corn than in such crops as wheat, oats, alfalfa, or clover.* This fact undoubtedly has an important bearing on the relatively high yields of corn fodder obtained.

In addition to the rainfall and evaporation, temperature is an important factor in the growth of corn, particularly with respect to the types that may be grown and the maturing of the crop. Table IV gives the mean, minimum, and maximum temperature, in degrees Fahrenheit, by months from April to September, inclusive, for the years 1909 to 1918, inclusive. The figures given for maximum and minimum temperature represent averages for the month or year, respectively. The mean temperature for any month is the average of the daily mean temperatures. It is seen from these figures that the seasonal mean temperature has been only 54 degrees and that it has varied slightly from year to year, the range being from 57 degrees in 1910 to 51 degrees in 1916.

*Briggs, L. J., and Shantz, H. L. The Water Requirement of Plants. U. S. Dept. of Agr., Bur. Plant Industry, Bul. 284.

TABLE IV.—MEAN, MAXIMUM, AND MINIMUM TEMPERATURES IN DEGREES F. AT THE JUDITH BASIN SUB-STATION BY MONTHS FROM APRIL TO SEPTEMBER OF EACH YEAR FROM 1909 TO 1918, INCLUSIVE.

(Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.)

	April			May			June			July			August			Sept.			
Year	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Seasonal mean
1909	35	44	25	49	60	38	58	68	47	63	74	50	65	78	50	59	68	49	55
1910	40	65	34	51	62	41	60	74	47	68	82	53	62	75	47	53	63	41	57
1911	38	51	26	48	59	37	60	71	47	62	77	45	58	70	47	50	62	38	52
1912	43	55	31	50	60	37	61	74	45	61	75	47	62	76	47	48	60	35	54
1913	43	55	31	49	63	38	60	73	48	62	76	48	65	81	49	55	72	40	56
1914	42	56	29	51	65	37	57	69	45	68	83	51	62	77	45	56	71	40	56
1915	50	62	37	49	59	38	52	62	42	58	69	46	66	81	51	49	59	38	54
1916	41	53	29	45	57	33	55	65	44	65	79	51	62	78	47	52	66	38	51
1917	35	44	27	46	57	35	55	67	42	60	85	53	63	78	47	56	69	43	54
1918	37	48	26	46	57	34	63	77	49	63	75	50	61	75	46	53	65	40	54
Total	413	533	295	484	599	368	581	700	456	630	775	494	626	769	476	531	655	402	543
Av.	41	53	30	48	60	37	58	70	46	64	78	49	63	77	48	53	66	40	54

Of perhaps even more importance is the shortness of the frost-free period, shown in Table V to have averaged only 122 days, or three to four weeks less than the average frost-free period in the corn-belt.

TABLE V.—DATE OF LAST KILLING FROST IN SPRING, FIRST IN FALL, AND THE LENGTH OF THE FROST-FREE PERIOD AT MOCCASIN, FOR THE YEARS 1909 TO 1918, INCLUSIVE.

Year	Last killing frost in spring	First killing frost in fall	Frost-free period
1909	May 17	Oct. 12	148
1910	June 2	Aug. 24	83
1911	May 6	Sept. 18	135
1912	May 12	Sept. 15	126
1913	May 19	Sept. 9	113
1914	May 12	Sept. 12	123
1915	May 5	Sept. 11	129
1916	May 16	Sept. 13	120
1917	May 30	Oct. 17	140
1918	May 28	Sept. 14	109
Average	May 18	Sept. 17	122

In a region of such low mean temperature and with such a short frost-free period, it is not surprising to find that corn, or at least the varieties tested under the methods employed, can not be depended upon to mature grain and must be regarded chiefly as a forage crop to be fed as dry fodder or as ensilage. Sometimes, in exceptionally favorable years, especially when the first killing frost does not occur until late in the fall, corn may mature in the Judith Basin; but since killing frosts may normally be expected before the crop has had time to mature, it would appear that the best practice would be to harvest the corn as a fodder crop. That has been done in all the experiments reported herein.

EXPERIMENTS WITH CORN

The greater part of the experimental work with corn at the Judith Basin Substation has consisted of testing this crop in rotations with other crops. The work was started in Field A in 1908 and additional rotations were started in Field B in 1914. Corn is included as a crop in forty rotations out of the forty-six being tested. Some of the rotations are for two years, in which corn alternates with either wheat, oats, or flax. Others are three-year rotations in which wheat and oats or barley and oats form the other crops. Corn is also grown in four-year rotations with two small grains

and a year of summer fallow or a green manure crop. In these cases a year of small grain always intervenes between the year of corn and the year of summer fallow or green manure crop. In longer rotations containing a sod crop, corn has been grown as the second crop from the sod. In some rotations the land is manured before being plowed for a crop of corn.

Besides being grown in rotations, corn is grown continuously by different tillage methods on some plots. Shallow spring plowing, deep fall plowing, subsoiling, spring listing, fall listing, and alternate cropping to corn and summer fallowing have been the methods tested in the continuous cropping series. A special experiment has also been conducted to determine the effect of dynamiting on corn and wheat yields.

All rotation plots and plots in the continuous cropping series are one-tenth of an acre in area. The rows have been planted 3.3 feet apart, making eleven rows to a tenth-acre plot 33 feet wide. The seed has been planted 12 to 18 inches apart in the row with a two-row corn planter. The corn plots have been kept free from weeds and harvested with a grain binder. Weights of dry corn fodder have been taken from each plot after the fodder has stood in the shock for several weeks, and yields are computed on an acreage basis. All yield data are for corn fodder as not enough mature grain has been produced in any year to make husking and separate weighing worth while.

Dakota 90-day corn was used in the rotations and continuous cropping series from 1909 to 1913, inclusive. From that time up to 1918 Northwestern Dent was used. During these years a number of different varieties of corn have been tested and, while some early flint and semident varieties have matured corn in favorable seasons, no variety has been found that can be relied upon in this respect. Some varieties do not get beyond the silking stage in this climate. The early flint varieties have produced less fodder than the semident and dent varieties and for this reason do not appear to be as well suited to conditions obtaining in the Judith Basin.

Northwestern Dent corn has been the most satisfactory variety tested. It is a reddish semident variety which is quite commonly grown for grain at lower altitudes. In the Judith Basin it produces

a good yield of fodder and at the same time generally reaches the glazing stage and begins to show signs of denting before being damaged by frost.

YIELDS OF CORN FODDER

On the basis of acre-tonnage, corn appears to be the largest-yielding feed crop that has been tested at the Judith Basin Substation. The results recorded since 1909, in fact, show the average yield of

TABLE VI.—AVERAGE ACRE-YIELDS IN POUNDS PRODUCED BY CORN, ALFALFA, BROME GRASS, AND RED CLOVER, FOR THE YEARS 1909 TO 1918, INCLUSIVE.

Year	Yield in Pounds per Acre			
	Corn	Alfalfa	Brome	Red Clover
1909	9456	3890	3063	3600
1910	2641	725	*518	†0
1911	5981	2360	1069	1100
1912	2961	2450	2436	1400
1913	4215	3715	1729	3000
1914	4310	3500	3571	2900
1915	6198	2300	1829	3000
1916	4423	1950	2614	3000
1917	3368	2300	1194	1100
1918	7152	2113	1571	2175
Average	5071	2530	1953	2128

*Four of the six brome plots failed on account of drought.
†Failure due to drought.

corn fodder to have been fully twice that of alfalfa, brome grass, or red clover. A comparison of the yields of these crops appears in Table VI. These average yields are for thirty-one corn plots, seven brome plots, two alfalfa plots, and one clover plot, all located in Field A. Weights in each case were taken after the crop was well cured in the field. Average yields have varied greatly from year to year, and it is noted that some of the best years from the standpoint of corn production have not necessarily been good years for other forage crops. Abundant moisture in the spring favors large yields of alfalfa or brome, and a very dry spring causes correspondingly low yields of these crops as they are generally harvested in the latter part of June or the first of July. Corn, however, receives the benefit of later rains. Thus in 1918 yields of alfalfa, brome grass, and clover were rather low, due to the dry spring, while the corn crop was benefited by late rains and gave a higher yield than in any year since 1909.

EFFECT OF THE PREVIOUS CROP ON YIELDS OF CORN FODDER

Corn fodder is produced under a system of continuous cropping to corn on six plots in Field A. It is grown on summer fallowed land on one plot, follows a crop of spring wheat in seven rotations, a crop of oats in seventeen rotations, and a crop of barley in one rotation. Thus Field A furnishes data for comparing the effect of the previous crop on yields of corn fodder. Average yields of corn fodder for the entire period, obtained after different crops and after fallow, are illustrated in figure 1. The average yields of fodder

TABLE VII.—EFFECT OF PREVIOUS CROP ON CORN YIELDS IN FIELD A, FOR THE YEARS 1909 TO 1918, INCLUSIVE.

Previous crop	Corn	S. Wheat	Oats	Barley	Fallow	Average
No. plots	6	7	17	1	1	31
Avg. Yield 1909	10428	9217	9146	8900	11530	9456
" " 1910	3024	2678	2494	2200	3300	2641
" " 1911	6433	6554	5748	6250	3850	5961
" " 1912						2961
" " 1913	4700	4564	3741	5200	6100	4215
" " 1914	4200	4643	4200	5200	3500	4316
" " 1915	7610	6186	5741	6500	6700	6196
" " 1916	5280	4357	4153	4800	4800	4423
" " 1917	4080	3514	3059	3100	4300	3368
" " 1918	7900	7200	6929	7800	6200	7152
Average	5968	5435	5023	5550	5587	5071

FIG. 1.—Average yields of corn fodder obtained after fallow and crops of corn, spring wheat, oats, and barley in Field A for the years 1909 to 1918, inclusive.

obtained each year after the different crops mentioned and after fallow are given in Table VII.

Corn following corn has given comparatively high yields for all years except 1914 when the average yield of corn fodder following corn was less than the average yield of all plots for that year. The average yield of corn fodder following corn is decidedly higher than the average yield of corn fodder obtained from summer fallowed land or following a small grain crop.

Results on summer tilled land have varied greatly from year to year. Corn after fallow gave better results in 1909, 1910, 1913, and 1917 than corn after any one of the crops named. However, the yield of corn fodder obtained on fallowed land in 1911, 1914, and 1918 was lower than the average yield obtained after corn, barley, spring wheat, or oats. The average yield obtained on fallow land is but little better than the average yield of corn fodder obtained after barley or spring wheat.

Corn after oats has given lower average yields of fodder than corn after barley or spring wheat.

The effect of the previous crop on corn yields in Field B is shown in Table VIII and graphically illustrated in figure 2. Corn

TABLE VIII.—EFFECT OF THE PREVIOUS CROP ON YIELDS OF CORN FODDER IN FIELD B FOR THE YEARS 1914 TO 1918, INCLUSIVE.

Previous crop	W. Wheat	Oats	Barley	Flax	Average
No. plots	7	2	2	4	15
Avg. Yield 1914......	3500	2900	4900		3645
" " 1915......	5464	5050	3100	7325	5590
" " 1916......	4086	4050	3700	4150	4047
" " 1917	3121	3300	3200	3475	3250
" " 1918......	6057	6300	5000	6375	6153
Average 1914-18.....	4446	4320	4160		4537
Average 1915-18.....	4682	4675	3975	5331	4760

FIG. 2.—Yields of corn fodder obtained after winter wheat, oats, barley, and flax in Field B.

is grown after winter wheat, oats, barley, and flax in this field. It is noted that average yields of corn fodder following flax have been higher than average yields obtained after any other crop in this field. The average yield of corn fodder following oats is higher than the average yield following barley in Field B, while the opposite is true in Field A. Differences are not very great in either case.

Table IX and figure 3 further compare yields of corn fodder obtained after a crop of corn with average yields obtained after small grains when the seed-bed preparation for the corn is the same. The average yields after corn are about 1000 pounds heavier than the average yields after small grains, regardless of whether the plowing is done in the spring or the fall.

FIG. 3. Yields of corn fodder obtained in Field A, on spring and fall-plowed land, after crops of small grain and after corn.

EFFECT OF TILLAGE METHODS ON YIELDS OF CORN FODDER

The continuous cropping series in Field A contains seven plots. Two of these are alternately cropped and summer fallowed. The other five are planted to corn each year, but a different method of seed-bed preparation is used on each plot. Plot A receives no treatment in the fall but is plowed to a depth of 3 inches in the spring and is harrowed once before seeding. Plot B is plowed to a depth of 7 inches in the fall, left rough during the winter, and double disked and harrowed before seeding in the spring. Plots C and D are alternately summer tilled and cropped to corn. The fallowed plot is plowed in the latter part of spring and is cultivated enough to keep down weed growth during the summer. The cropped plot is double disked and harrowed just before seeding. Plot E is plowed to a depth of 7 inches in the fall. At the time of plowing a subsoiler is run in each alternate furrow and this goes down 3

TABLE IX.—EFFECT OF DIFFERENT TILLAGE METHODS ON YIELDS OF CORN FODDER FOR THE YEARS 1909 TO 1918, INCLUSIVE.

	Field A								Field B	
Cultural treatm't	Spring plowed		Fall plowed		S. Till	Subsoiled	F. List	S. List	Spring plowed	Fall plowed
Plot	Rotations	A	Rotations	B	C-D	E	F	G	Rots.	Rots.
Previous crop	Small grain	Corn	Small grain	Corn	Corn	Corn	Corn	Corn	Small grain	Small grain
No. plots	16	1	9	1	1	1	1	1	13	2
Avg. yield 1909....	8603	10100	10011	11120	11530	11420	11700	7800		
" " 1910....	2621	2760	2386	2900	3300	3650	3260	2550		
" " 1911....	5893	7250	6174	7000	3850	4780	6700	*		
" " 1913....	4225	5000	3683	4000	6100	5800	4450	4550		
" " 1914....	4500	4900	4122	3700	3500	5000	3800	3600	3780	2300
" " 1915....	5888	7700	5911	8450	6700	8000	7200	6700	5427	6650
" " 1916....	3775	5400	5056	6200	4800	6200	4400	4200	4054	4000
" " 1917....	3381	4600	2844	4300	4300	4300	3800	3400	3323	2775
" " 1918....	7213	8000	6733	7200	6200	8800	8000	7500	6277	5350
Average	5122	6190	5213	6097	5587	6439	5923	5038	4572	4215

*Corn did not germinate.

or 4 inches deeper than the plow, or, in other words, the soil is loosened up to a depth of 10 or 11 inches. This plot is then treated in the same manner as Plot B. Plot F is listed in the fall to a depth of about 7 inches. As a lister works poorly in the soil at the station, it has been the custom to make the ridges and furrows by a system of backfurrowing with a plow. In this way a back furrow alternates with a dead furrow and leaves the land similar to the ridged condition produced by listing. The land is left in a rough condition during the winter and is double disked and harrowed before seeding in the spring. Plot G receives the same treatment as Plot F except that the listing is done in the spring.

FIG. 4. Average yields of corn fodder obtained by different tillage methods at the Judith Basin Substation for the years 1909 to 1918, inclusive.

There are also sixteen spring-plowed plots and nine fall-plowed plots in the rotations in Field A, and thirteen spring-plowed plots and two fall-plowed plots in the rotations in Field B, where corn is grown on land previously cropped to some small grain. All fall-plowed plots in the rotations are handled in the same way as Plot B of the continuous-cropping series. Spring-plowed plots are plowed to a depth of 7 inches in the spring and double disked and harrowed before seeding.

The yields obtained by these different tillage methods for each year from 1909 to 1918, inclusive, are given in Table IX and graphically illustrated in figure 4, which shows the average yield obtained

by each tillage method in the continuous-cropping series. The highest average yield—6439 pounds per acre—has resulted from subsoiling. However, this is an increase of only 249 pounds to the acre over the average yield obtained from Plot A where the land is plowed shallowly in the spring and is not double disked before seeding. It is doubtful if the extra yield obtained would pay for the extra labor involved in subsoiling.

There is but little difference in the average yields obtained from spring-plowed or fall-plowed land. Results have varied from year to year but the averages indicate that the farmer may plow in the fall or in the spring as best suits his convenience.

Yields obtained from the summer-fallowed plot have generally been comparatively low.

Listing has given lower average yields than plowing and the method is certainly not suited to the type of soil found in the Judith Basin. It may have advantages on more sandy soils as it is a cheaper method than plowing. On soils adapted to listing, the land is not ordinarily disked before seeding but the rows are planted in the furrows.

EFFECT OF DYNAMITING THE SOIL ON THE YIELDS OF CORD FODDER

Dynamiting as a means of breaking up hard and impervious subsoils and creating a storage reservoir for soil moisture has attracted a good deal of attention in some localities. Accordingly an experiment was started at the Judith Basin Substation in the fall of 1912 and continued until the close of the season of 1917 to determine the value of such a practice on the dry bench lands of the Judith Basin. The experiments were arranged between the Office of Dry-Land Agriculture and the Du Pont de Nemours Powder Company, to be carried on cooperatively with the Montana Agricultural Experiment Station.

The land chosen had been cropped for several years and was fallowed during the summer of 1912. Sixteen one-fourth acre plots were used for the experiment and corn and wheat were the crops grown, eight plots being cropped to corn and eight to wheat each year. Four plots were continuously cropped to wheat and four were continuously cropped to corn. Corn and wheat alternated on the other eight plots. Thus there were four plots each year where corn followed corn and four plots where corn followed wheat.

The corn was grown under four systems of tillage each year, which were:

1. Corn grown on plots not dynamited at all.
2. Corn grown on plots dynamited every other year where corn was the first crop after dynamiting.
3. Corn grown on plots dynamited every other year.
4. Corn grown on plots dynamited every year.

All dynamiting was done in the fall of each year, starting in 1912. The holes for the dynamite were 15 feet apart each way and were 31 inches deep.

All plowing for the 1913, 1914, 1915, and 1917 crops was done in the spring, while the plowing for the 1916 crop was done in the fall. The plowing on both dynamited plots and those not dynamited was to a depth of 6 or 7 inches. Plots were double disked and harrowed before seeding in the spring.

A study of Table X shows some slight advantage from the use of dynamite but not enough to warrant the trouble and expense.

TABLE X.—EFFECT OF DYNAMITING ON YIELDS OF CORN FODDER AT THE JUDITH BASIN SUBSTATION FOR THE YEARS 1913 TO 1917, INCLUSIVE.

Treatment	Previous crop	Yield					
		1913	1914	1915	1916	1917	Avg.
Dynamite each year	Corn	2640	9700	2115	4400	3600	4491
First crop after dynamite	"	2240	8500	2120	3400	3600	3972
Second crop after dynamite	"	2880	8700	1695	4600	3200	4215
Not dynamited	"	2200	8400	1840	4400	3400	4048
Dynamite each year	Wheat	2580	5700	1685	2400	3200	3113
First crop after dynamite	"	2480	3400	1530	2800	3200	2682
Second crop after dynamite	"	2440	6900	2165	2600	4000	3621
Not dynamited	"	1880	3900	1480	2800	2600	2532

Higher yields were obtained when corn followed corn than when corn followed wheat in this test, which coincides with the results in other tests reported in this bulletin.

EFFECT OF STABLE MANURE ON YIELDS OF CORN FODDER

Stable manure is applied to the corn plots of rotations 67 and 68 in Field A and to the corn plot of rotation 246 in Field B. The manure is applied to the corn plot of rotation 67 just before plowing in the spring. The corn is followed by oats on disked corn ground, and wheat follows the oats on spring-plowed land. Rotation 9 is similar to rotation 67 in all respects except that the corn receives

no manure and the oats are grown on spring-plowed land. Rotation 68 was started in 1910 on land that had previously been vacant. This rotation is the same as 67 except that the oats and wheat are grown in reverse sequence and that the second crop following the manure is spring plowed in 67 and fall plowed in 68. Rotation 1 is similar to rotation 68 except that no manure is applied to the former rotation and the corn plot in rotation 1 is fall plowed while the corn plot in rotation 68 is spring plowed. Rotations 245 and 246 were started in 1914 and are similar in all respects except that the corn plot in rotation 246 is manured before plowing in the spring. These are both two-year rotations in which flax follows corn.

Rotation 43 is the same as rotation 3 in all respects except that the oat plot in the former receives an application of manure just before plowing in the fall. Corn follows the oats and wheat follows the corn, all on fall-plowed land in both rotations.

In all cases well-rotted manure is spread over the plots by hand at the rate of about ten tons per acre.

The yields obtained from the eight rotations mentioned are given in Table XI. In the case of rotations 68 and 1, wheat and oat yields for 1910 and oat yields for 1911 are not counted in figuring the average yields for these crops. This is because these crops in rotation 68 were grown on land that had not yet received an application of manure in the years mentioned. However, the yields are of interest in comparing the uniformity of the soil in rotations 68 and 1 and indicate that the soil is fairly uniform.

The effect of the manure on corn yields, where corn is the first crop grown after the application of the manure, should receive first attention. Table XI shows that the average yield of corn fodder grown in rotation 67 is over fifteen hundred pounds more than the average yield of corn fodder grown in rotation 9. The corn receiving the benefit of an application of manure in rotation 67 has yielded more than the corn in rotation 9 in all years except 1910. The effect of the manure has not been as marked in rotation 68 as in rotation 67, but even in this case the maured plot in rotation 68 has yielded more than the unmanured plot in rotation 1 in all years except 1915 and 1916. Corn fodder has given an average yield of 644 pounds more in rotation 68 than in rotation 1. Stable manure has also increased the yields of corn fodder in Field B, as shown

TABLE XI.—YIELDS IN ROTATIONS 67, 68, 246 AND 48 WHERE ONE CROP RECEIVES THE BENEFIT OF AN APPLICATION OF MANURE COMPARED WITH YIELDS IN SIMILAR ROTATIONS THAT DO NOT RECEIVE ANY MANURE.

	Crop	1909	1910	1911	1913	1914	1915	1916	1917	1918	Avg.	Gain or loss by manuring
Rot. 67—Crop manured	Corn		2600	9250	6100	5600	8100	4800	4200	9700	6294	*1581
" " second crop	Oats		26.9	53.7	86.2	47.8	100.9	61.8	27.2	50.3	56.9	*11.3
" " third crop	S. Wheat		10.0	24.5	24.7	19.6	39.6	21.5	12.3	25.0	22.2	*3.9
Rotation 9	Corn		3300	5700	4900	4900	4900	3100	3700	7200	4713	
	Oats		22.2	56.5	61.2	47.8	75.3	43.1	17.2	41.6	45.6	
	S. Wheat		10.0	20.8	23.5	16.6	29.3	22.3	8.5	15.0	18.3	
Rot. 68—Crop manured	Corn		2900	6600	4500	5000	4800	4500	4100	8500	5113	*644
" " second crop	S. Wheat		10.6	18.6	30.0	17.0	39.8	29.3	8.0	28.5	24.5	*2.5
" " third crop	Oats		25.0	62.0	66.9	59.0	75.6	45.0	20.0	47.2	52.3	*8.1
Rotation 1	Corn		2600	4550	2900	4400	6900	4800	2500	7100	4469	
	S. Wheat		11.7	28.0	24.0	21.6	23.8	23.0	12.5	20.8	22.0	
	Oats		21.2	50.6	57.8	51.2	63.1	45.6	16.9	30.6	44.2	
Rot. 246—Crop manured	Corn					4000	6000	4700	4000	7600	5260	*320
" " second crop	Flax					10.7	21.6	12.1	5.5	13.8	12.7	*.2
Rotation 245	Corn					2300	8500	4100	3500	6300	4940	
" "	Flax					11.7	18.9	12.3	6.6	13.2	12.5	
Rot. 48—Crop manured	Oats	62.8	18.1	54.3	69.7	49.0	80.0	43.4	17.2	39.7	48.2	*4.1
" " second crop	Corn	9700	2100	7250	2200	3300	5400	4100	2500	8800	5039	†155
" " third crop	S. Wheat	31.6	11.3	20.5	23.5	17.6	34.1	22.5	8.3	18.3	20.9	†1.4
Rotation 3	Oats	61.5	17.5	49.6	55.6	58.2	65.9	44.3	16.3	29.7	44.1	
" "	Corn	11,200	2600	5750	4200	3800	6500	5000	2100	5900	5294	
" "	S. Wheat	31.0	15.0	22.3	26.3	18.5	28.5	27.3	10.2	21.3	22.3	

*Gain. †Loss.

by a comparison of the yields obtained from rotations 246 and 245. The manured plot in rotation 246 yielded higher than the unmanured plot in rotation 245 in all years except 1915.

The average yields of corn fodder obtained from each of these six rotations are graphically illustrated in figure 5. Average yields of corn fodder from the three manured rotations and from the three unmanured rotations are also given. It is seen that stable manure has increased yields in all years except the dry year of 1910 and the wet year of 1915, when the unmanured plots in rotations 9, 1, and 245 gave a higher average yield of corn fodder than the manured plots of rotations 67, 68, and 246. Average yields for the entire period show that the use of stable manure has resulted in an average increase of about one thousand pounds of corn fodder per acre.

FIG. 5. Average yields of corn fodder obtained from manured plots, compared with average yields from unmanured plots.

EFFECT OF CORN ON SUCCEEDING CROPS

The yields of oats, spring wheat, and barley, following summer fallow, corn, and other crops, are given in Table XII for each year from 1909 to 1918, inclusive. It is seen that oats have been grown after corn, four small grain crops, two green manure crops, fallow, and three sod crops. Spring wheat has been grown after corn, fallow, two small grain crops, and two green manure crops. Barley has been grown after corn, fallow, and two small grain crops.

The highest average yield of oats has been obtained on summer-fallowed land, and the next highest after green manure crops. The average yield of oats after winter wheat is also slightly higher than after corn, but the average for oats after winter wheat is for

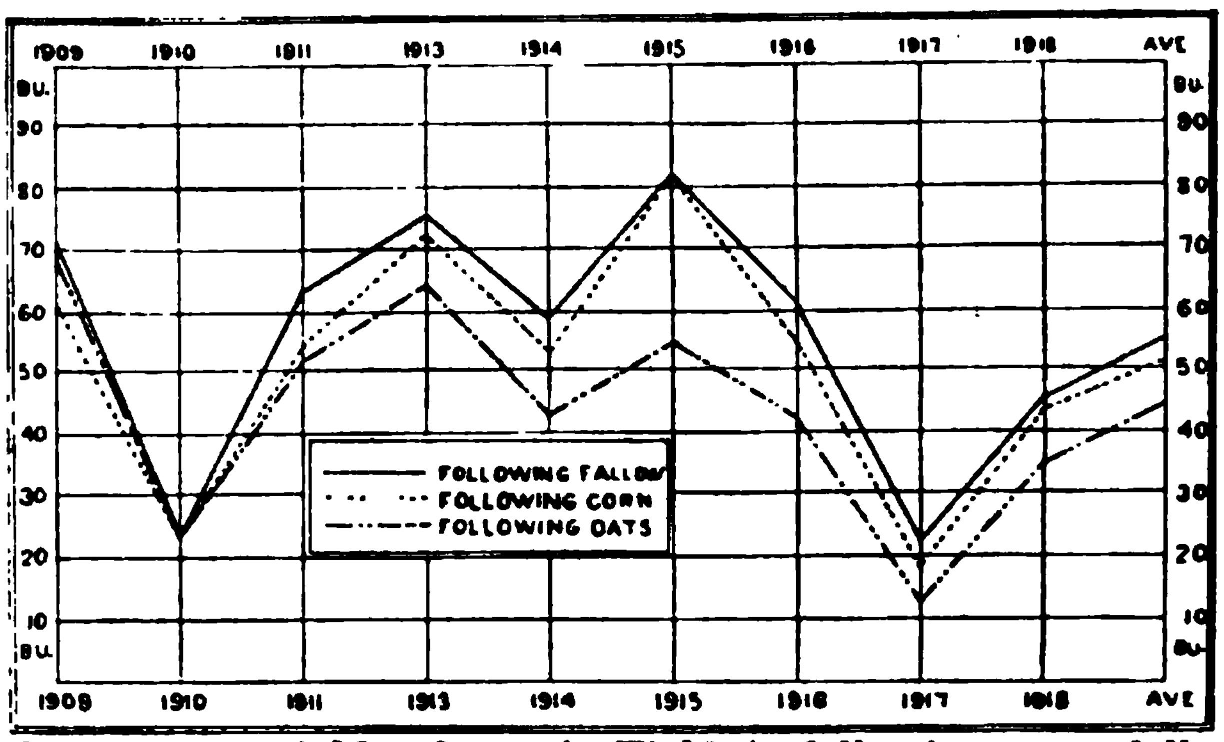

FIG. 6. Average yields of oats in Field A, following corn, fallow, and oats.

seven years while that for oats after corn is for nine years. If averages are worked out for the same years in both cases, it is found that the average yield of oats after corn is greater than after winter wheat. The average yield of oats after corn has been decidedly larger than the average after any other grain crop or after a sod crop.

Average yields of oats obtained by continuous cropping and after corn and fallow are graphically illustrated in figure 6. Little difference is observed in the first two years but in all other years oats after fallow or corn have given decidedly higher average yields than oats following oats. The average yield of oats following corn has generally fallen below the average yield obtained on summer-tilled land, but the differences have not been great.

The average yield of spring wheat grown on corn land has been the highest obtained, but in general the previous crop has had but little effect on spring wheat yields. Average yields of spring wheat following corn, fallow, and spring wheat are graphically illustrated in figure 7. It is seen that spring wheat after corn yielded practically the same as spring wheat after fallow for all years except 1910 and 1911. These results indicate that corn can take the place of summer fallow without any reduction in the yield of a following crop of spring wheat.

TABLE XII.—EFFECT OF PREVIOUS CROP ON YIELD OF OATS, SPRING WHEAT, BARLEY AT THE JUDITH BASIN SUBSTATION FOR THE YEARS 1909 TO 1918, INCLUSIVE.

Crop	Previous crop	No. plots	1909	1910	1911	1913	1914	1915	1916	1917	1918	Total	Avg.
Oats													
	Corn	8	61.6	24.0	55.3	72.2	53.0	81.2	54.4	18.7	43.8	464.2	51.6
	Oats	4	69.4	23.3	52.5	64.4	43.1	54.5	42.4	13.4	35.6	398.7	44.3
	S. Wheat	7	64.5	21.4	52.8	61.6	51.9	71.0	45.8	15.9	37.2	422.1	46.9
	W. Wheat	1	....	....	53.1	70.6	52.1	77.8	51.2	15.6	43.1	363.5	51.9
	Barley	1	57.8	19.3	53.7	64.4	54.0	65.6	50.0	20.3	36.6	421.7	46.9
	Peas pl. under	2	71.2	21.0	52.0	75.3	46.7	86.2	57.3	18.8	42.7	471.2	52.4
	Winter rye pl. under	2	68.7	25.7	56.8	75.9	54.3	85.8	55.5	18.5	49.5	490.7	54.5
	Fallow	3	70.5	23.6	63.2	76.2	58.7	81.4	61.4	21.8	46.2	503.0	55.9
	Alfalfa	1	56.8	14.3	33.1	30.6	47.1	41.8	29.3	14.4	31.3	298.7	33.2
	Clover	1	72.5	22.8	37.8	50.3	50.6	74.3	35.9	14.1	35.9	394.2	43.8
	Brome grass	2	62.5	17.8	22.5	38.6	21.5	36.4	23.6	5.0	23.5	251.4	27.9
S. Wheat													
	Corn	11	34.1	11.3	23.2	23.8	19.1	34.5	24.5	10.2	22.0	2002.7	22.5
	S. Wheat	5	34.8	11.1	24.0	23.1	16.6	28.0	19.4	8.6	14.3	179.9	20.0
	Oats	4	35.1	11.0	23.4	23.8	18.6	32.6	23.2	10.8	20.4	198.9	22.1
	Fallow	4	34.1	7.2	20.1	22.9	19.5	35.3	24.2	10.4	22.5	196.2	21.8
	Peas pl. under	1	28.3	11.0	20.5	20.5	18.3	31.6	25.0	6.5	17.8	179.5	19.9
	Rye pl. under	1	34.0	9.0	19.0	28.0	15.1	27.8	22.1	12.7	18.5	186.2	20.7
Barley													
	Corn	1	42.7	10.6	29.7	34.6	21.6	37.1	26.3	5.2	28.1	241.7	26.9
	Barley	4	46.2	12.5	27.8	27.3	18.7	26.0	18.9	3.7	22.3	203.4	22.6
	Oats	1	39.1	11.6	....	31.7	21.2	34.0	21.8	3.6	26.0	188.4	23.6
	Fallow	1	49.4	15.8	27.5	32.7	25.8	37.1	27.5	6.7	36.0	258.5	28.7

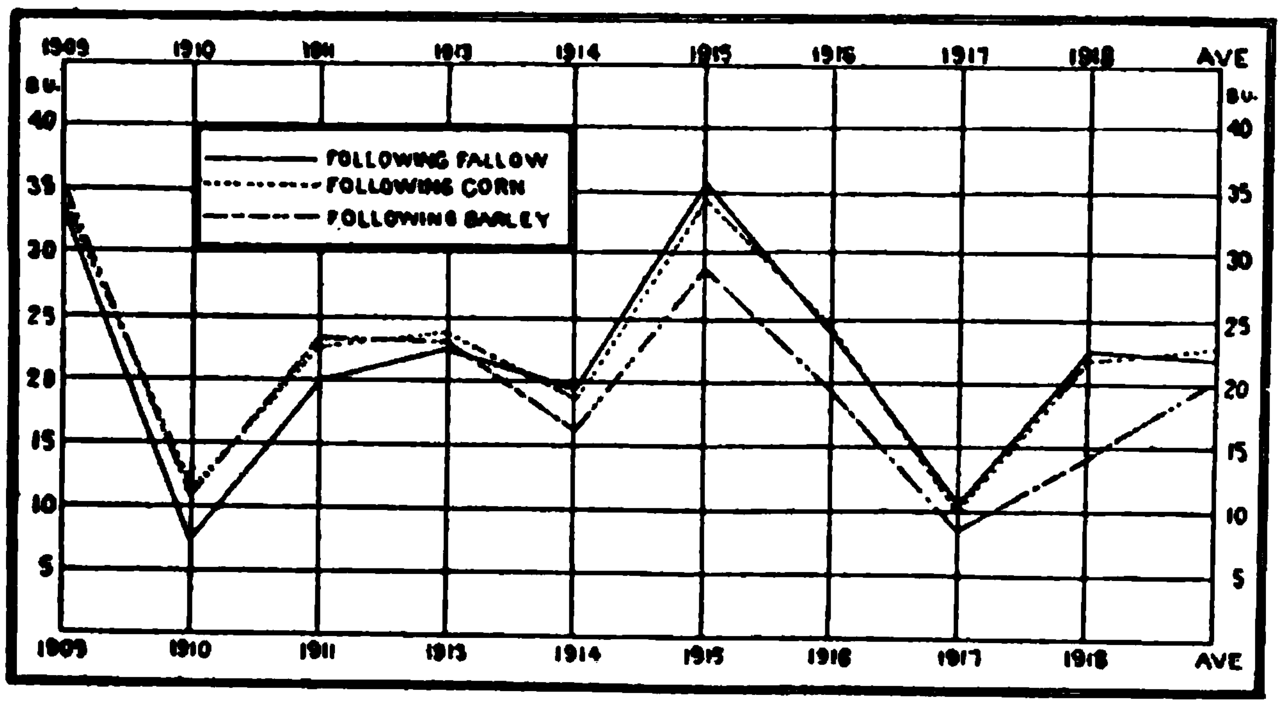

FIG. 7. Average yields of spring wheat in Field A, following corn, fallow, and spring wheat. (For "barley" read "spring wheat" in the legend.)

Barley after fallow or corn has yielded better than after barley or oats. Average yields of barley following fallow, corn, and barley are graphically illustrated in figure 8. Only small differences are

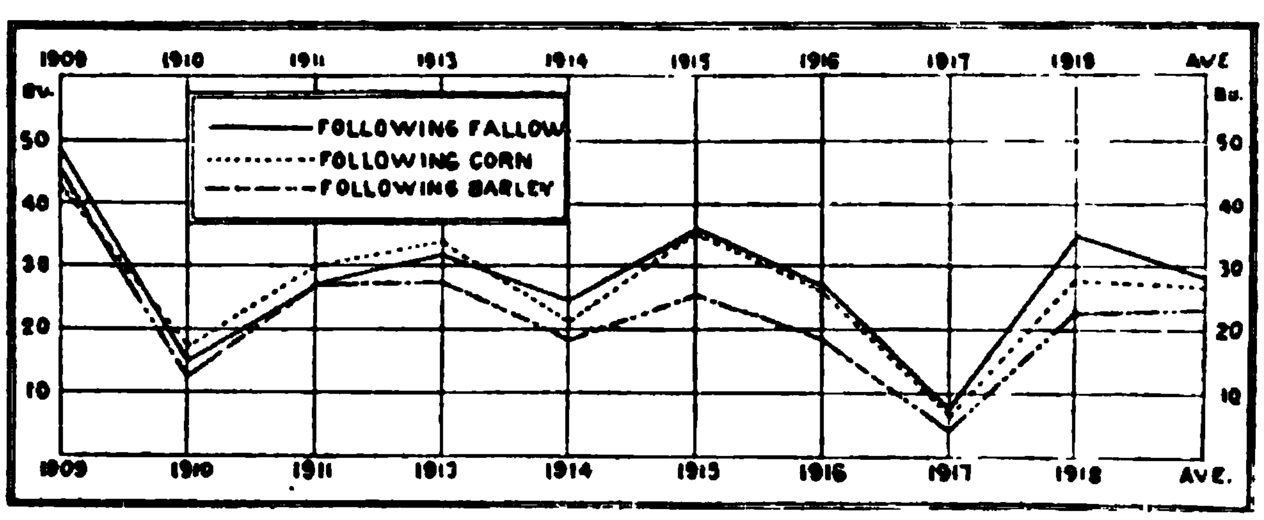

FIG. 8. Average yields of barley in Field A, following corn, fallow, and barley.

observed for the first three years, but after that barley following fallow or corn has generally given higher yields than when following barley. As in the case of oats, the average yield after fallow has been a little higher than the average yield after corn.

DISKING vs. PLOWING CORN STUBBLE

The effect of disking corn stubble as compared with plowing it is shown by the data presented in Table XIII and illustrated in figure 9. Differences have not been great in any case. Yields of spring wheat on disked corn land, spring-plowed corn land, and fall-plowed corn land have been very nearly equal each year. More variation is observed in the case of oat yields and flax yields.

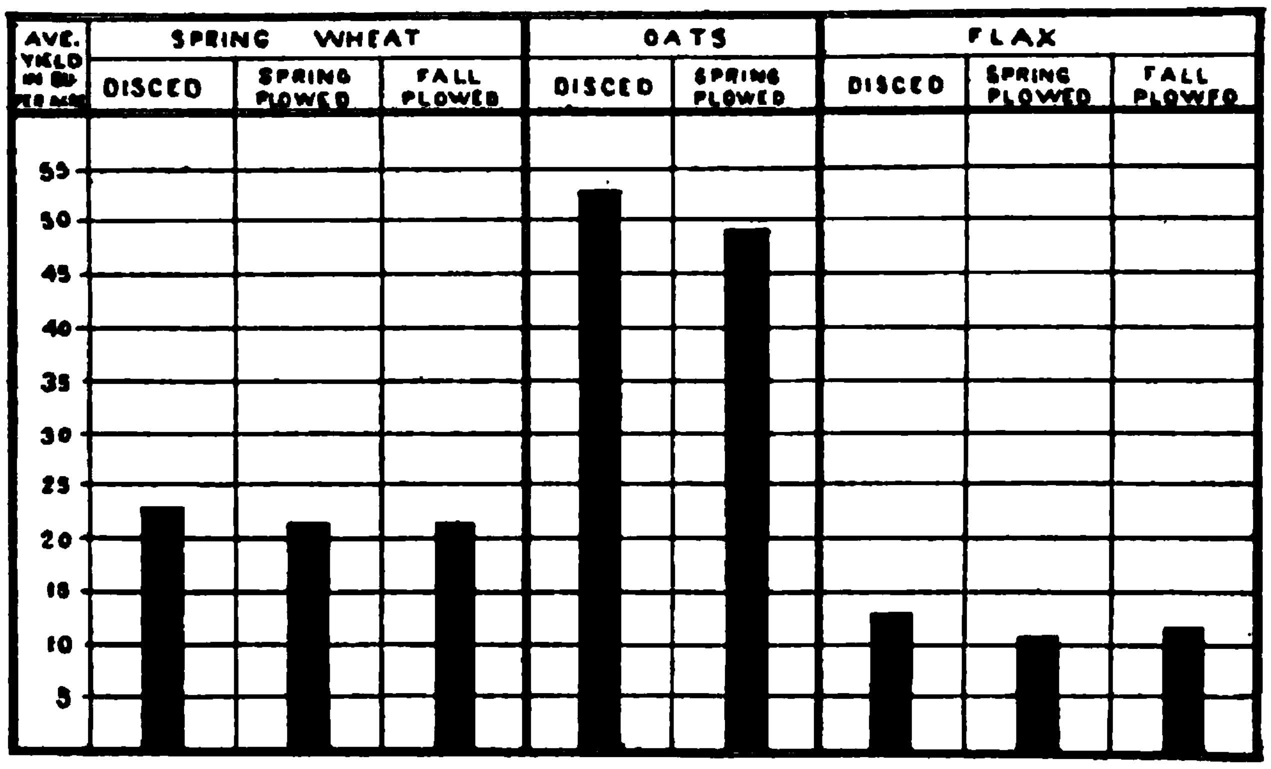

FIG. 9. **Average yields of spring wheat, oats, and flax obtained on disked corn ground, compared with average yields of these crops obtained on plowed corn land.**

TABLE XIII.--YIELDS OF SPRING WHEAT, OATS AND FLAX ON DISKED CORN LAND COMPARED WITH YIELDS ON PLOWED CORN LAND FOR THE YEARS 1909 TO 1918, INCLUSIVE.

Year	Spring Wheat			Oats		Flax Field B.		
	Disked	Sp. pl.	Fall pl.	Disked	Sp. pl.	Disked	Sp. pl.	Fall pl.
1909	35.0	33.1	31.3	57.3	72.4			
1910	10.8	11.6	13.2	24.4	23.1			
1911	23.9	21.3	21.4	55.6	54.5			
1913	23.6	23.8	24.9	75.1	63.1			
1914	19.4	18.5	18.1	54.2	49.2			
1915	34.4	31.8	31.3	83.3	75.0	20.2	15.6	17.5
1916	24.7	21.8	24.9	57.4	45.6	12.2	11.2	12.6
1917	10.5	10.0	9.3	19.8	15.7	6.1	5.8	6.4
1918	22.7	21.0	19.8	44.7	41.3	13.5	9.3	9.5
Avg.	22.8	21.4	21.6	52.4	48.9	13.0	10.5	11.5

SUMMARY

1. Experiments with corn have been conducted at the Judith Basin Substation since 1908. Most of the work has related to growing corn in rotations and by different tillage methods.

2. No varieties of corn have been found that can be depended upon to mature a grain crop. The growing season is too short and the prevailing temperatures too low to permit the development of mature seed corn in most years.

3. Northwestern Dent corn and some other varieties can gen-

erally be depended upon to approach maturity near enough to make a fine quality of fodder which can be fed dry or as silage.

4. The average yield of corn fodder in the rotations has been over twice as great as the average yield of alfalfa, or brome grass, or red clover.

5. Corn has yielded higher following corn than when grown on summer-fallowed land or when following a small grain crop. However, the benefits of growing corn in a rotation are such that this method is to be preferred to growing corn continuously on the same land.

6. Tillage methods.

(a) Subsoiling has resulted in a higher average yield of corn fodder than any other tillage method tested, but shallow spring plowing without disking has given an average yield of only 249 pounds per acre less. The increase in yield by subsoiling has not been sufficient to pay for the increased cost of production.

(b) Plowing has generally resulted in higher yields than listing. Whether the plowing is done in the fall or in the spring, or whether it is shallow or deep seems to have but little effect on yields of corn fodder on the substation soil.

(c) Listing is not adapted to the soil found in the Judith Basin. It has resulted in lower average yields than plowing. However, it offers some advantages on soils adapted to listing as it is a cheaper method than plowing.

(d) Summer fallowing as a preparation for growing corn fodder has not increased yields.

7. Dynamiting has not increased yields sufficiently to justify the practice.

8. Stable manure applied to corn plots at the rate of about ten tons per acre just before spring plowing has increased average yields of corn fodder by about one thousand pounds per acre.

9. Yields of oats, spring wheat, and barley have in all cases averaged higher after corn than after a small grain crop and have averaged as high or almost as high as when these crops are grown on summer-fallowed land.

10. Spring wheat, oats, and flax have all given slightly higher average yields on disked than on plowed corn land.

UNIVERSITY OF MONTANA

AGRICULTURAL EXPERIMENT STATION

BOZEMAN, MONTANA

BULLETIN NO. 133 DECEMBER, 1919

Seventeenth Annual Report of the State Entomologist of Montana

The Alfalfa Weevil, a serious pest of alfalfa, which has spread northward from Utah until it has now appeared on the Montana boundary in Idaho.

BY

R. A. COOLEY

Seventeenth Annual Report of the State Entomologist of Montana

INSECT PESTS OF 1919.

THE MITES AND TICKS (ACARINA).

Red Spider (*Tetranychus bimaculatus* Harvey). There was the usual number of reports of injury from this pest to raspberry and currant bushes. Beans in eastern Montana suffered somewhat from red spider attack.

Pear-Leaf Blister Mite (*Eriophyes pyri* Pagnat). In general the fruit crop of the Bitter Root Valley suffered less injury from this pest during the past year than for several years previously.

CRICKETS AND GRASSHOPPERS (ORTHOPTERA).

Black Cricket (*Gryllus assimilis* Stew.). This common black cricket was again present in Big Horn county. It was also reported injurious in Rosebud and Yellowstone counties where it was combated with poisoned bran mash the same as used for grasshoppers. The best results were obtained when the arsenical content was increased somewhat over the standard amount.

Warrior or Yellow-Winged Grasshopper (*Camnula pellucida* Scudd.). In ten counties of the state this grasshopper occurred in enormous numbers and during the latter part of the summer the State Entomologist's forces gave their entire time to aiding farmers to save their grain fields from this insect. Lack of sufficient money for traveling prevented a greater service to the state.

Big-Headed Grasshopper (*Aulocara elliotti* Thom.). In recent years the big-headed grasshopper has not caused much difficulty, but during 1919 it was encountered in great numbers in Gallatin, Beaverhead, and Madison counties, where it was doing damage to grasses.

THE TRUE BUGS, PLANT LICE, ETC. (HEMIPTERA).

Box Elder Bug (*Leptocoris trivittatus* Say.). This insect ordinarily confines itself to the box elder but was reported to have injured fruit in the vicinity of Joliet.

Cottony Maple Leaf-Scale (*Pulvinaria acericola* Walsh & Riley). This louse has been known to be present on shade trees in the cities of Missoula and Kalispell for some years but during the present season there was a great increase and injury was reported.

Bedbugs (*Cimex lectularius* Linn.). More than the normal number of requests for advice on "how to rid the house of bugs," came to us this season. The cyanide fumigation method, although it necessitates some danger and expense, is recommended and excellent results have been obtained.

Chinch Bug (*Blissus lencopterus* Say.). The country south of Glasgow where chinch bugs were abundant in 1911 was examined thoroughly again this season but no evidence of a reoccurrence of the pest could be found.

Cabbage Louse (*Aphis brassicae* Linn.). The cabbage louse was observed to be much more abundant than for some time past. Inquiries were numerous as to how this insect could be destroyed.

False Chinch Bug (*Nysius ericae* Schill). On account of being mistaken for the real chinch bug (*Blissus lencopterus* Say.) this insect causes alarm wherever found. Although it is a bad pest in gardens, in no way does it approach its eastern relative in the amount of destruction which it can cause.

Oyster Shell Bark Louse (*Lepidosaphes ulmi* Linn.). The oyster shell scale was present in less than normal numbers in the Bitter Root Valley in 1919.

Sugar-Beet Root-Louse (*Pemphigus betae* Doane). This was more abundant than it has been since 1916 and damage was done in the beet-growing districts of the state.

MOTHS AND BUTTERFLIES (LEPIDOPTERA).

Imported Cabbage Worm (*Pontia rapae* Linn.). This caused an increased loss to the cabbage crop. Many calls for information on control methods were received and it is safe to say that this insect has not been so plentiful for several years past.

Corn Ear Worm (*Heliothis obsoleta* Fab.). This insect is becoming more important among the pests of eastern Montana and this

year was especially abundant. The first generation of worms attacks corn when only a few inches high while a later generation gnaws out the kernels at the tips of the ears.

Mourning Cloak Butterfly (*Euvanessa antiopa* Linn.). The larvae of this species, known as the "spiny elm caterpillar," eat the foliage of elm, willow, and cottonwood. Specimens were received from several localities where they were reported numerous.

Cecropia Moth (*Samia cecropia* Linn.). This large moth and caterpillar, often mistaken for the silkworm, was abundant at Glasgow, Union, and Sidney.

Cutworms (*Noctuidae*). Cutworms were as abundant as usual in gardens all over the state. Almost every kind of garden plant was attacked. In some places onions suffered severely from being chewed off near the surface of the soil.

Pale Western Cutworm (*Porosagrotis orthogonia* Morr.). Throughout twelve counties in the northern and eastern sections of the state, as well as in two counties of the central district, this insect caused enormous losses to the grain crop. In many cases what the worms partially destroyed the drought finished, but in as many other instances partial loss from drought was made complete by the ravages of the worms. This is a new pest in Montana and can not be combated by the ordinary methods employed against cutworms.

Parnassius Butterfly (*Parnassius smintheus* D. & H.). This beautiful butterfly was abundant in the mountainous sections of the state during a short period last summer.

Tent Caterpillar (*Clisiocampa* sp.). In some sections of northern and eastern Montana the wild rose foliage was completely destroyed before July 1 by this insect. Currant bushes, not protected with sprays, also suffered injury.

The Oblique-Banded Leaf-Roller (*Archip rosaceana* Harris). This year saw an increase of this insect in the Bitter Root Valley and a considerable amount of damage was done to the foliage of apple trees.

Mediterranean Flour Moth (*Ephestis kuehniella* Zell.). This insect is regarded as the most important of all pests which infest flour mills, warehouses, grain mills, and stores. The larvae feed upon all kinds of grain products. The fine web which they spin

causes a clogging of machinery besides their being the cause of introduction of filth into the materials. Fumigation, intense heat, or intense cold, are the remedies employed.

Sugar Beet Webworm (*Loxostege sticticalis* L.). Primarily a pest of sugar beets, this insect is also the cause of much injury to gardens and alfalfa in nearly all parts of the state. A slight decrease in its occurrence was noted this season. The destruction of thistle, which farmers in the northern part of the state wished to harvest for stock feed on account of drought conditions, has been a bad factor with this pest.

Codling Moth (*Cydia pomonella* Linn.). This well-known pest of the apple, formerly present only in the vicinity of Missoula, is becoming more widespread in the Bitter Root Valley. Elsewhere it is by all odds the worst insect enemy which apple growers have to fight and its establishment here will make necessary on the part of the orchardists more effort toward insect control.

FLIES (DIPTERA).

Wheat Stem Maggot (*Hylemyia cerealis* Gillette). This maggot, which bores through the central stems of wheat, was present again this season. The field in Yellowstone county, where the pest was first discovered in this state, was again a complete loss. Drought and cutworms in the northern part of Montana caused maggot injury to be largely overlooked.

Onion Maggot (*Phorbia ceparum* Meade). A slight decrease in the presenec of this insect was noticeable this year although in some localities considerable loss from it was incurred.

Cabbage Maggot (*Phorbia brassicae* Boche). No injury from this pest was reported this season.

Currant Fruit Fly (*Epochra canadensis* Leow.). A normal amount of damage to currants and gooseberries from this insect, which in some places has caused the growing of these crops to be abandoned, was reported to the State Entomologist.

House Fly (*Musca domestica*). House flies were exceptionally abundant during the past season and were the source of much annoyance, not to speak of their activity in the spreading of disease.

THE BEETLES (COLEOPTERA).

The Common Meal Worm (*Tenebrio molitor* Linn.). **The "Cadelle"** (*Tenebrioides mauritanicus* Linn.). These well known

insects of flour mills were reported from Great Falls. Losses due to these insects are largely preventable by fumigation.

Flea Beetles (*Epitrix* sp.). Flea beetles, attacking potatoes, tomatoes, and all kinds of garden plants just as they were coming out of the ground early in the season, were the source of much trouble and numerous complaints concerning them came to our attention from all parts of the state.

Cottonwood Blotch Miner (*Odontota* sp.). In many parts of Montana the cottonwood trees were severely injured by this insect which works between the surfaces of the leaves. On account of its mode of attack it can not be destroyed by ordinary spraying, and as its life-history is not thoroughly known other means which might prove effective for destroying it have not been found.

June Beetles (*Lachnosterna* sp.). These large beetles, the parents of white grubs, were observed in greater abundance than in former years.

Colorado Potato Beetle (*Leptinotarsa decemlineata* Say). Potato beetles were present in usual abundance. This is one of the few insects about which it may be said that methods of control are almost universally known. Paris green is the standard remedy but it is being replaced to a large extent by a cheaper arsenical, arsenite of zinc, which has been recommended during the past three years by the State Entomologist.

Wireworms (*Elateridae*). Wireworms again occupied their place of importance among the grain pests of the state. Numerous inquiries were received as to what they were and how they could be destroyed.

Confused Flour Beetle (*Tribolium confusum* Duv.). A persistent pest of stored cereals, crushed feed, and other starchy food, was found in the feed bins of the poultry department of the Montana Experiment Station.

Alfalfa Weevil (*Phytonomus posticus* Gyll.). During the latter part of August a trip was made by automobile along the Oregon Short Line Railway from Dillon to Monida and through the Centennial Valley in an effort to determine if the alfalfa weevil was spreading into Montana. Careful search of alfalfa fields revealed no evidence of the pest in this territory, which is the most exposed of any part of Montana to migrations of this insect from infested regions of Idaho and Utah.

CURRENT ENTOMOLOGICAL PROBLEMS

Some of the outstanding entomological problems of the present time are the following:

PALE WESTERN CUTWORM

For several years we have been giving attention to cutworms in garden and field crops in Montana and gradually information of considerable value is being brought together. It is evident that there is a considerable variety of very destructive cutworms in the state, though in any one year the trouble is caused mainly by some one or another single species. The species which is best known in Montana is undoubtedly the army cutworm (*Chorizagrotis auxiliaris* Grote) which at times has caused extensive damage to fall wheat, but during the past few years there has appeared another which is quite as serious. This is the pale western cutworm (*Porosagrotis orthogonia* Morr.) which has been mentioned in previous reports, but which we are, year by year, recognizing as more serious than we had suspected. Without much doubt over a million dollars' worth of grain was destroyed in Montana in 1919. Similar extensive damage occurred in Canada, just north of Montana, in the same year. There appear to be four reasons why this is an unusually injurious cutworm. (1) It has a long period of larval feeding extending from the middle of April for upward of two months. In this it contrasts strongly with the army cutworm which, when abundant, attracts attention in April and is all through feeding by May 10, or about a month in all. (2) Its damage is done so late in the season that it is too late to put in a crop of spring grain, as can be done sometimes when the grain has been eaten off by the army cutworm. (3) The pale western cutworm feeds under ground and we know of no practical way to kill it. Poisoned bran mash scattered thinly over the surface, so effective in controlling the army cutworm, does not affect this species. (4) It is not heavily attacked by parasites and continues year after year, gradually becoming more abundant and destructive. This cutworm has already become a serious problem in Montana and is receiving careful attention from this office. Under our Experiment Station research funds we are studying its habits and control. Excellent progress has been made and we have much information of value but no satisfactory remedy has yet been worked out.

GRASSHOPPERS

The state collection of insects contains upward of one hundred species of Montana grasshoppers. With so many in the state it is not strange that one or another of them becomes abundant and injurious occasionally. In 1919 grasshoppers were more than usually injurious. Early in the season in May, reports began to reach the office of a species which was appearing in alarming numbers in the far eastern part of the state. Specimens accompanying inquiries turned out to be *Eritetix tricarianata.* Mr. Strand went to the locality where this grasshopper was injurious in June and advised with the farmers on its control.

Later in the season, the warrior grasshopper (*Cannula pellucida*) appeared in great numbers in most parts of the state. Our notes show it to have been present in great numbers in Gallatin, Missoula, and Beaverhead counties. In some localities this grasshopper was present in enormous numbers, migrating more or less in the air and congregating in the foothills around the valleys for egg-laying purposes, where the ground was literally covered with these insects busily engaged in boring into the earth and depositing their pods of eggs. There can be little doubt that some trouble will be experienced in 1920 from the grasshoppers originating from these eggs unless steps are taken to destroy either the eggs or the young grasshoppers soon after hatching. While on a trip of searching for the alfalfa weevil in the counties of Gallatin, Beaverhead, and Madison, Mr. Parker and Mr. Strand encountered large numbers of the same species which was very abundant in Montana sixteen years ago, namely, the big-headed grasshopper (*Aulocara elliotti* Thomas). This is a true grass-feeding species and its occurrence in large numbers is always important. It is one of Montana's worst insect enemies to range grass. In earlier years I have seen the range completely bared of grass by this species.

It is a remarkable thing that grasshoppers of the *Melanoplus atlanis* group which were very abundant and destructive in different parts of Montana as recently as 1918, and especially one year earlier, were not abundant in the state in any place so far as we know in 1919. In 1917 and 1918 when Melanoplus was abundant we observed that wherever these insects were numerous, parasitic flies were also present in great numbers. We believe that these flies

were the cause of the disappearance of the grasshopper. It is noted now that these parasitic flies are not present in connection with the outbreaks of the three grasshoppers listed above as injurious in 1919. We look upon this as indicating that the grasshopper difficulty will be continued through several years.

SUGAR-BEET WEBWORM

The common name, sugar-beet webworm, is not a satisfactory one for the insect (*Loxostege sticticalis* Linn.) which in recent years has been unusually abundant and has caused general apprehension among farmers and gardeners. During the season of 1919 this insect occurred in large numbers, though probably not quite as abundantly as during the preceding year, and was the occasion of a considerable amount of correspondence arising over the central and northern portions of Montana. There were two broods, the first appearing in May and early June and the second mainly in August. The injury done was chiefly to garden plants and to the Russian thistle. The presence of large numbers of this insect in grain fields, feeding on the Russian thistle, caused the farmers to become anxious in many cases and they wrote to us for information regarding what might be expected. It was feared that they would attack the grain when the Russian thistles were all gone. Experience has indicated that this webworm does not attack wheat and we were able to assure the farmers that no damage would be done. In some cases farmers were afraid to plant a new crop of grain because they knew that this insect was still in the soil from the preceding year, appearing there as larvae in long silken tubes, vertically placed in the soil. A number of letters were written to such farmers. Real injury, however, was done in gardens where beets, spinach, and a few other plants were eaten. This insect is capable of doing extensive damage in sugar beet fields.

ALFALFA

The alfalfa weevil (*Phytonomus posticus* Gyll.), which attracted the attention of the residents of Utah in the year 1904 and has spread and caused extensive loss to growers of alfalfa and stockmen in that state, has continued to spread to the northward. This very injurious insect has in a relatively brief time extended into parts of three states by direct spreading and during the same time has made two jumps, one into Colorado and another into western Idaho,

and is continuing to extend itself. According to information recently secured from the Bureau of Entomology office at Salt Lake the following counties in Idaho now have the weevil: Madison, Fremont, Bonneville, Bingham, Bannock, Bear Lake, Franklin, Oneida, Power, Cassia, Ada, Payette, Canyon, and Washington. One of these counties, Fremont, is the first county over the boundary from Montana. The weevil has been spreading perhaps fifty miles a year and without much doubt during the next year or two will be found to occur in Montana. It takes several years after being introduced for this insect to multiply in sufficient numbers to do real damage or to become sufficiently numerous to be discovered. It may be, therefore, that this insect already occurs undetected in Beaverhead, Madison or Gallatin County. The quarantine which we now have in force is effective only against the transportation of the weevil by rail. Such transportation would lead to its establishment in more or less remote localities, while by spreading overland it gradually spreads across the country.

With the coming of this insect into Montana we will be confronted by an entirely new and a very serious condition. This insect is primarily injurious to alfalfa and seriously reduces the tonnage, making it necessary to do a large amount of work in order to produce a profitable crop of hay. It is also of much importance to stockmen who are vitally interested in the alfalfa crop and the prices which they must pay. The coming of this insect into Montana will, therefore, be looked upon eventually as a serious matter.

The state of Idaho has recently removed the quarantine between the counties that are infested and those that are not in the state, thereby making it possible to move hay without restriction in that state. For this reason it will be necessary for Montana to establish a quarantine against the whole of Idaho in order that our own interests may be protected.

FOUL BROOD OF BEES

Our first knowledge of the presence of American foul brood of bees in Montana came in the spring of 1911 when a sample of this disease was sent in from Joliet. In the report of the State Entomologist for 1911 a recommendation was made that a law be passed providing for inspection and control. The nature of the legislation needed was pointed out in the ninth report. In the tenth report,

one year later, the subject was again briefly discussed, pointing out the situation and obvious needs. In nearly every report since that time we have called attention to the progress that the disease is making in its spread over the state, to the seriousness of the situation in the bee industry, and to the legislation needed. Nothing has been done.

Meantime, American foul brood disease has spread extensively and has entered practically every important honey-producing section of the state. Many beekeepers have been put out of business . Abandoned colonies of bees containing infectious material have been left where the bees died, continuing to spread the malady.

Representatives of the State Beekeepers Association called upon the State Entomologist in their official capacity in December, 1919. asking that this office cooperate with them in an effort to draw up a suitable law and once more make an effort to have it passed by the legislature. Accordingly, we are engaged in a review of the various bee laws in the United States and intend to have a bill ready before the next meeting of the legislature which shall have the combined support of the beekeepers of the state and of the State Entomologist.

THE CODLING MOTH (CARPOCAPSA POMONELLA LINN.)

The codling moth, the general insect enemy of the apple, has been present in Montana for at least twenty-five years, although isolated and confined largely to some of the older towns in which large apple trees are growing. Considerable attention was given to its habits and control in earlier years and various publications have been issued from this office. With the growth of the orchards in the fruit-growing sections and the development of the orchard industry, this insect has come into more prominence in recent years, due to the increase in its numbers under favorable conditions found on the larger trees. Fruit growers in western Montana have recently brought to the attention of this office the fact that the codling moth occurs in injurious numbers and that it is necessary to adopt energetic means of control. During the past year we received also letters from other parts of the state asking for assistance. We believe that the reason for the greater interest in this subject in 1919 was due to the unusually warm season. The weather dried off and became hot early in the year and made it possible for a destructive

second brood of the moth to develop. I do not expect that in other years the codling moth will be as serious in Montana as in some other states because of the natural limitations placed upon a second brood. It will, however, be sufficiently abundant to cause loss to fruit growers and energetic measures should be adopted to hold it in control. Fruit growers who have codling moth should spray for it. Most fruit growers have more than one insect pest or fungous disease and all should adopt a spraying program which should be consistently carried out year after year.

LEAF-ROLLER OF THE APPLE

Our attention has been called to the leaf-roller which appeared in injurious numbers on apple trees in the Bitter Root Valley in 1919. In some instances large numbers of trees were more or less completely denuded. It is impossible for us to say at the present time which one of two species is the cause of the trouble. The fruit-tree leaf-roller (*Archips argyrospila* Walker) is sometimes spoken of as the Colorado leaf-roller and growers locally have spoken of this as being that insect. However, in past years we have in a number of instances reared the oblique-banded leaf-roller (*Archips rosaceana* Harris) from the Bitter Root Valley. In some instances this latter insect has done rather serious damage to a limited number of trees. We shall have to wait for further developments of next season before we can determine which of these species is present. Satisfactory results in control can be secured by the use of miscible oils applied as a spray in the spring as soon as the weather warms up sufficiently to make spraying operations possible. It is not believed that this will be a pest which will continue year after year. Its history has been that it has occurred intermittently.

FLEA BEETLES

The season of 1919 was notable for the number of flea beetles which occurred. These minute beetles, with swollen hind legs enabling them to jump away when disturbed, are present more or less generally in small numbers each year but in the past season they occurred in such numbers as to cause rather extensive damage in gardens, on tomato and potato plants, and in sugar-beets. These insects work early in the season, destroying young plants soon after they come out of the soil. The stand in sugar-beet fields is sometimes seriously reduced by great numbers of flea beetles completely